THE CAUSES AND PREVENTION OF
AIRLINE BAGGAGE HANDLER BACK INJURIES:
SAFE DESIGNS REQUIRED WHERE BEHAVIOUR AND ADMINISTRATIVE SOLUTIONS HAVE HAD LIMITED EFFECT

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ABSTRACT

Back injuries have consistently been the most common types of injuries suffered by people at work. They have been a significant worker injury problem in most, if not all, industrialised countries for many years and manual handling has long been established as a significant task related back injury causal factor. Airline baggage handling has remained an area of work which relies heavily on manual handling and back injuries to airline baggage handlers was first identified as an emerging problem in the mid 1970s. However, manual handling injuries to baggage handlers remained a problem in the mid 1990s and effective long term solutions to the problem seemed not to have been developed. Mitigation measures across the airline industry worldwide then focused on worker behaviour, lifting techniques and basic manual handling training. This study, in five parts, was undertaken to firmly establish the magnitude of the problem across the industry, to identify known causal factors and investigate the efficacy of preventive measures being applied across the industry.

This research project established that the manufacturers of the jet airliners used by the airlines in this study had not previously been acquainted with the issue of baggage handler back injuries. The manufacturers' willingness to participate in searching for solutions was ascertained early in the project. However, they remained reluctant to make design changes to their aircraft.

The magnitude of the baggage handler back injury problem across the airline industry was also clearly brought to attention in this study. It was found that in the period 1992 to 1994 inclusive, baggage handler back injuries cost $US21million per annum across only 16 airline companies and each year their baggage handling workforce experienced average lost time injury frequencies over 41.5 per million hours worked, solely due to back injuries. These baggage handler back injury frequencies were forty times higher than the results reported by best practice organisations "all injuries" reporting.

This study also canvassed the opinion of airline safety professionals and airline baggage handlers concerning baggage handling tasks and working environment

related causal factors. Their considerations on methods to prevent baggage handler back injuries were also sought. There was a significant degree of consensus between the safety professionals and the baggage handlers. Both groups ranked stacking baggage in narrow-body aircraft as the highest risk baggage handling task and heavy baggage was identified as a significant problem by both groups. The safety professional and baggage handler groups both wanted baggage weight limits set and enforced across the industry. However, recent research showed a limit below 10kg per baggage item would have been necessary to effectively control the manual handling risk.

A major focus of this research project was also to measure the effect of *ACE* and *Sliding Carpet*, two commercially available retro-fit baggage systems, on the risk of back injuries to baggage handlers stacking baggage within Boeing B737 narrow-body aircraft. Using three separate measurement techniques, biomechanical modelling, direct measurement of postures and consensus of expert ergonomist opinion, this study found that baggage handlers stacking baggage in *ACE* had significantly higher risk of back injury than when stacking baggage in Sliding Carpet or when stacking baggage when neither system was fitted to the aircraft. Furthermore, it was found that due to the inward opening baggage compartment door of B737 aircraft encroaching on the handlers' workspace, baggage handlers stacking baggage into *Sliding Carpet* were at a significantly higher risk of back injury when stacking baggage into stowage positions where the aircraft door affected the baggage handlers' lifting and stacking postures.

In the final stage of the project, the theoretical change in risk of baggage handler back injuries associated with use of a prototype baggage loading machine, the *RTT Longreach Loader*, was estimated. The *RTT Longreach Loader* was found to significantly reduce the manual handling load on baggage handlers when stacking baggage into narrow-body aircraft compartments. The *RTT Loader* effectively eliminated the need to lift baggage within the baggage compartment and significantly altered the dynamics of the baggage handling tasks. Using the *RTT Longreach Loader*, handlers were required only to push and pull baggage at the same level, compared to the lifting and stacking of baggage required when working without the *RTT Longreach Loader*.

This study showed that the manual handling load on baggage handlers due to the stacking of baggage in narrow body aircraft represented a considerable back injury risk and that the administrative hazard controls that had been previously applied by the airline industry, such as lifting technique training for workers and the introduction of a per item upper baggage weight limit of 32kg had failed to stem the tide of manual handling injuries. Only those engineering design interventions that eliminated lifting of baggage and thereby significantly reduced the biomechanical load on baggage handlers, solutions such as the *RTT Longreach Loader*, *RampSnake* and robotics solutions, were likely to result in significant reductions in the instance of baggage handler back injuries.

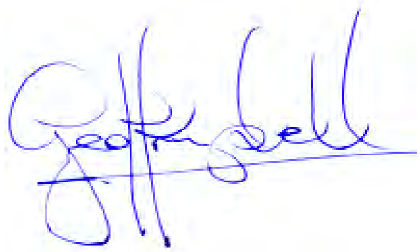
These outcomes clearly question the efficacy of administrative hazard controls that focus on worker postures and behaviours in any high risk manual handling working environment and suggest that engineering design hazard controls which reduced or eliminated biomechanical load on workers would provide significantly lower risk of injury.

This study also showed that it was possible to engage the major stakeholders, the manufacturers of plant and equipment, industry bodies, unions, companies and workers, to apply pressure for improvements in a global industry. However, there was a significant level of industry inertia against rapid improvements and the focused intervention of the OH&S regulators was necessary in order to create a step change across the industry.

STATEMENT OF AUTHORSHIP

Except where explicit reference is made in the text, this Thesis contains no material published by others nor extracted in whole or in part from a Thesis by which I have qualified for or been awarded another degree or diploma. During the course of the research described in this Thesis, three journal articles were published and numerous presentations made to aviation industry and safety profession symposia relating to the research and its findings.

No other person's work has been relied upon or used without due acknowledgement in the main text and bibliography of this Thesis.



Geoffrey Dell January 12, 2007

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I would also like to acknowledge with thanks the involvement of the Human Factors and Ergonomics Society of Australasia and thanks also to the Certified Practicing Ergonomists who gave their time and professional opinions in response to the survey that helped identify the critical differences in manual handling risk associated with the two in-plane baggage systems being analysed in this study.

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I would also like to recognise the help of the many baggage handlers who participated in the survey in this study and the Qantas personnel with baggage handling experience who helped with the laboratory trials and the risk assessments, in particular my sincere thanks go to Barry Morris, Ken Lockwood, Russell Wallace, Warren Barnes, Bob Brazil, Bob Dunkley, Mike Burgess, Chris Barber, Robert Seymore, Mark Bernhardt and last but not least, Graham Clough.

The valuable input of the airline safety professionals, the members of the National Safety Council of America International Air Transport Executive and the Australasian Aviation Ground Safety Council, is also acknowledged with thanks.

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Many more people helped along the way and to all of these people I owe a sincere debt of gratitude.

DEDICATION

This Thesis is dedicated to the late Captain John W. Benton, former Manager Flight Safety Investigation at TAA/Australian Airlines. John was an advocate of system safety principles from the early nineteen sixties and was pivotal in the emergence of that airline as a leader in safety performance in the global aviation industry. I will be forever grateful to John for his recognition of the safety management potential of a young would-be pilot and the mentor role he played in the development of my early career as a safety professional.

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PREFACE

In February 1990, having been in the role of Manager, Ground Operations Safety for Australian Airlines for a little over a week, the writer first became aware of the back injury problem faced by airline baggage handlers when the Airline's Brisbane Airport OH&S Representative, Des Anderson, entered my office and placed a 100 mm long, 6 mm diameter, curved surgical steel rod on my desk and demanded to know what management were doing about the problem.

When it became quickly became apparent to Des that I didn't have the foggiest notion what he was talking about, he proceeded to explain his reasons for concern.

A baggage handler from Des' workgroup had a short time before had the surgical steel rod removed from his back. The rod had previously been implanted in the person's back to immobilise his spine following a serious back injury while stacking baggage in a Boeing B737 baggage compartment. However, when the surgical steel rod had been inserted in the person's back, it had been **straight**. Apparently, after a period of convalescence from the original injury and subsequent surgery, the person had made such a good recovery that he returned to work as a baggage handler. Within three months he had to be re-admitted to hospital for the pin to be removed and replaced, supposedly because it had bent due to the repetitive load of handling baggage and cargo.

While the validity of the decision to return to baggage handling duties following the surgery could be questioned, it was apparent that a significant load, or loads, had been placed on the surgical steel pin to cause it to bend.

As a result of Des Anderson's visit, I began to look into what if any action the airline had previously taken regarding manual handling in the airport operation. Up to that time there had been very little effort made to reduce the manual handling injury risk to baggage handlers. There was no limit at all on the weight of baggage they routinely handled, manual handling training was rare and where it was conducted, it was inappropriate for the baggage handling environment.

It seemed to me that manual handling injuries to baggage handlers were the biggest OH&S issue facing the airline at that time.

This research project directly evolved from the interest spawned by Des Anderson's visit.

CHAPTER ONE: INTRODUCTION

In many airlines around the world, manual handling of passenger baggage consistently results in high rates of injury. The literature shows that the problem has been recognised for many years and that a range of interventions have been attempted which have focused largely on changing the nature and methods of the work by such means as placing maximum limits on the weight of baggage and training personnel in supposed correct lifting techniques. The effectiveness of these and other administrative prevention methods are discussed in this Thesis.

Also, the literature suggests that the design of airline aircraft has an impact on injury causation due to the confined working environment of aircraft baggage compartments. The first phase of this study explored whether the aircraft manufacturers had taken the baggage handler injury issue into consideration in the aircraft design process. This stage of the project showed that the issue had not before been a part of the aircraft design formula.

The second phase of this study explored the magnitude of the problem across the global aviation industry. Safety professionals from major airlines were surveyed to obtain baggage handler back injury occurrence data and their opinions were sought on the causes of the problem and their views on possible solutions. This stage of the study confirmed that baggage handler back injuries were a major OH&S problem for the industry and identified that meagre intervention attempts had been made to that point that were mostly focused on baggage handler technique, work procedures and other administrative controls.

At that time, the literature was also devoid of any papers reporting on the injury issues from the perspective of the baggage handler workforce. To redress this, Phase 3 of this study surveyed baggage handlers' opinions on the causes of injuries suffered by their workgroup and their ideas regarding appropriate methods of injury prevention. Perhaps not surprisingly, the baggage handlers' consensus on causation and prevention was not dissimilar to that of the safety professionals.

The literature showed that there have been a small number of attempts to find engineering design solutions. Two of these supposed solutions involved systems installed in the aircraft cargo compartments and two involved ground based baggage loading equipment.

In Phase 4 of this study, laboratory trials were conducted to identify and measure the effect both of the two in-aircraft systems had on baggage handler back injury risk. The trials were conducted using a full size mock-up of an aircraft baggage compartment which was adjustable and simulated the physical environment of the aircraft with each of the systems fitted. The trials were conducted using volunteer baggage handlers and they were video-taped simultaneously in three, ninety degree, axes to provide clear perspective of postures adopted by the trial subjects. To maximise the probability of a definitive outcome from the trials, three separate methods were employed to measure differences in back injury risk between the systems.

In the first measure, the video of each baggage handler was analysed using a computer-based biomechanical modelling program. Second, the differences in trunk rotation and reach were directly measured from still frame photos taken from the video of the postures adopted by the trial subjects when loading baggage, and thirdly, twenty leading Australian ergonomists were shown videos of the baggage handlers loading baggage in the laboratory trials and based on their observation of the postures adopted by the trial subjects using each system, their opinions were surveyed on the differences in back injury risk. The outcomes were conclusive, all three measurement methods delivered equivalent statistically significant results.

In Phase 5, the final stage of the study, risk assessments were conducted with Qantas baggage handlers on the injury reduction benefits of using one of the two new types of ground based baggage loading equipment. This study found that the new loading equipment significantly reduced the injury risk to baggage handlers.

1.1 THE WORK OF THE AIRLINE BAGGAGE HANDLER

It would be difficult to gain an understanding of the causes and prevention of airline baggage handler back injuries without first having an understanding of the manual nature of the work of airline baggage handlers. Around the world, airport owners, aircraft ground handling companies and airlines rely heavily on manual handling to achieve the transfer of baggage and cargo at airports.

The number of times an item of passenger baggage is manually handled depends on the design of the passenger terminal, the type of aircraft operating the flight, and the type of support equipment available to the baggage handler.

In a typical airport operation, from the time the passengers lodge their baggage at check-in prior to a flight, each item of baggage may be handled manually by up to four different people, at different stages of the baggage transfer process, before being stacked inside the aircraft by a fifth person, as described below (see Figure 1.1). At the completion of a flight, the sequence is reversed with up to four people handling each item of baggage before it is delivered back to the passenger in the arrivals hall.

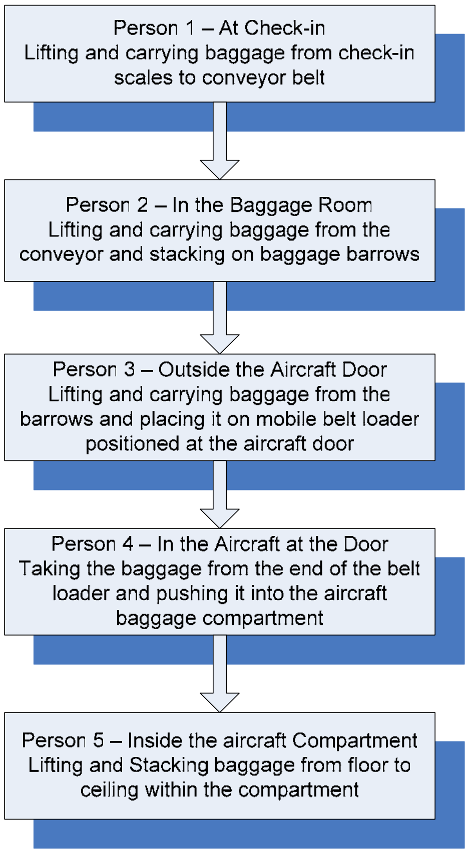

Figure 1.1
Typical Baggage Handling Tasks: Check-In To Aircraft Departure

At many airports worldwide, particularly the older or smaller airports, these manual baggage handling tasks begin immediately after the passengers present themselves at the check-in counter. The check-in agent may be required to manually lift and carry the baggage from the check-in scales to the conveyor belt to start the baggage on its journey towards the aircraft [See Figure 1.2[1]].

At many smaller airports, the conveyor behind the check-in counter gives the impression of a mechanised method of handling baggage matching that of the large international airports. However, the reality is often somewhat different. In many cases, the conveyors at smaller airports do nothing more than transfer the baggage through the wall and leave a pile of bags on the floor to be lifted, carried, sorted and stacked manually by the baggage handlers, as Figure 1.3 shows.

[1] Photograph courtesy of http://augustachronicle.com/images/headlines/011702/Bag_Check.jpg

Figure 1.2
Check-in staff required to lift and carry baggage to the rear conveyor

Even the modern, hi-tech baggage handling systems provided at large international airports worldwide, do little to address the manual baggage handling issue faced by contemporary airline baggage handlers. Of course, in large airports, passenger check-in locations are usually a significant distance from the aircraft and the baggage conveyor systems allow for the bags to be quickly and efficiently moved to the airports' baggage sorting areas. However, when the bags arrive at the end of the conveyor in the sorting room, baggage handlers are required to manually transfer each item of baggage from the conveyor, as the example in Figure 1.4 shows.

Figure 1.3
A smaller airport: Conveyor delivers baggage into a pile on the ground

Figure 1.4
In the baggage room: Taking bags from the conveyor to stack onto trailers or into containers

In the baggage room, two parallel systems of work commence dependent almost solely on the type of aircraft operating the flight.

The first system of work applies to baggage destined to be loaded onto *narrow-body aircraft*, such as the Boeing B717, B727, B737, McDonnell

Douglas DC9, MD83 and MD87 and Fokker F28 & F100, seating up to around 150 passengers. These aircraft are designed to have the baggage bulk loaded, one bag at a time. Accordingly, in the baggage room, when baggage is being consolidated for these narrow-body aircraft, the baggage is manually transferred from the baggage conveyor and stacked in bulk onto trailers [see Figure 1.5] for subsequent transport to the aircraft by tow vehicle. Once there, each individual item of baggage has to be manually loaded into the aircraft from the trailers, either directly from the trailers as shown in Figure 1.6, or via a mobile belt loader positioned at the door, as shown in Figure 1.7.

Figure 1.5
Transferring bags from conveyor to trailers in the sorting room at Buenos Aires

Figure 1.6
Loading baggage into the doorway of a B737 aircraft directly from a trailer at Melbourne

After the baggage has been transferred into a narrow body aircraft, each bag may then be handled up to twice more, firstly by a worker positioned inside the aircraft doorway who has the task of pushing the baggage from the doorway into the interior of the aircraft's baggage compartment [see Figure 1.8], and secondly by another baggage handler working in the interior of the compartment who must lift and stack the baggage inside the compartment [see Figure 1.9], from floor to ceiling and working from the inside far wall of the compartment back to the doorway, effectively filling the entire compartment space with baggage.

Figure 1.7
Using a belt loader at the doorway of a narrow-body aircraft in Buenos Aires

Figure 1.8
At Stockholm, working in the doorway, taking bags from belt loader and pushing them into the baggage compartment

Figure 1.9
Stacking baggage inside a narrow body aircraft

The second system of work applies to *wide-body aircraft*, such as the Boeing B747, B767, & B777, Airbus A300, A310, A330 & A340, Lockheed L1011 and the McDonnell Douglas DC10 & MD11. Wide body aircraft each seat in excess of 200 passengers and are fitted with containerized baggage systems. In the baggage room the majority of baggage for each flight must be stacked within the containers [see Figure 1.10] before the loaded containers are towed out to the aircraft and mechanically transferred into the aircraft [see Figure 1.11].

Figure 1.10
In the sorting Room: Transferring bags from conveyor to containers

Figure 1.11
Loading containers into a wide-body aircraft at Dallas/Fort Worth[2]

Such containerization has significantly reduced the need to manually load individual bags into wide-body aircraft as described above. However, it has not eliminated it entirely. There is, in fact, one small baggage compartment in all wide-body aircraft in the tail section of the fuselage which is used for bulk loading of baggage. These compartments generally hold up to about 70 items of baggage which must also be manually loaded in a similar fashion to that of narrow-body bulk loading. In the baggage room, baggage intended for the bulk hold of a wide-body aircraft is stacked on trailers, using a similar system of work to that for narrow-body aircraft. However, once out at the aircraft, due to the additional height above the ground of wide-body bulk hold doorways, mobile belt loaders are always used. Baggage lifting and stacking inside the bulk hold is achieved manually in a similar fashion to the baggage compartments of narrow-body aircraft, as Figure 1.12 shows.

[2] Photograph reproduced from ACI (1996)

Figure 1.12
Stacking baggage inside a wide-body B747 aircraft bulk hold

In addition, at airports the world over, prior to every flight of a wide-body aircraft, baggage handlers are required to manually push loaded containers off the container trailers, known as “dollies” through-out the industry, onto the rear platform of the container/pallet loader positioned at the aircraft door [see Figure 1.13]. No mechanised systems have been provided to complete this task.

All the manual baggage handling tasks described here were the direct result of the aircraft designers’ decisions. The manual methods of baggage transfer and stacking were a part of the intended baggage transfer solution. That the designers should be open to criticism for not providing comprehensive materials handling solutions seems beyond doubt, since some parts of the system seem to have been designed well and yet in other areas, such as those described above, the designers appear to have provided little or no solution at all.

Furthermore, if these intentional manual baggage handling tasks aren’t cause enough for concern, baggage handlers also routinely carry out additional extraordinary manual handling activities at airports.

Figure 1.13
Pushing a container off the dolly onto the container loader rear platform[3]

Additional Manual Handling Tasks Usually Carried out by Baggage Handlers

In addition to those manual handling tasks outlined above that make up the intended baggage transfer processes, baggage handlers worldwide routinely undertake additional manual tasks related to manipulation of various items of equipment. One such task is the manual pushing and pulling of loaded baggage trailers, both within baggage sorting rooms and outside on aircraft parking tarmacs [see Figure 1.14]. Although baggage trailers are designed to be towed by vehicles, on a daily basis at nearly all airports, the baggage handlers inevitably need to move baggage trailers when no tow vehicles are available. In such instances, there is no other means available to the baggage handlers than manual handling of the trailers.

While some airlines discourage this practice, others actually mandate it. This latter group of airlines do not allow tow vehicles to drive near to their aircraft for fear of a collision which could render the aircraft unserviceable and adversely effect the safety of flight, particularly if the damage was to go unreported or unnoticed. In the operations of these airlines, the tow vehicle drivers disconnect the loaded trailers some distance away from the aircraft

[3] Scene from video "The Airside Code", Aviation Training Association, Sussex (1999)

and the baggage handlers must push and pull the barrows into the final position at the aircraft. Manually pushing and pulling loaded trailers around the aircraft, as shown in Figure 1.14, is an "every flight" occurrence for the baggage handlers of those airlines.

There are also two more manual handling tasks undertaken by baggage handlers in some airlines. Those tasks are the manual pushing and pulling of passenger steps [see Figure 1.15] and belt loaders [see Figure 1.16].

Figure 1.14
View from aircraft doorway - pushing and pulling loaded baggage trailers.
(Note the second loaded trailer (at left) has been left some distance from the aircraft)

To keep capital costs down, these airlines have purchased passenger steps and belt loaders designed to be towed by a tractor instead of the much more expensive units which are themselves motorised. Usually such airlines require their baggage handlers to manually position this equipment at the aircraft doors on arrival from a flight and then manually pull them away again prior to the subsequent aircraft departure.

Figure 1.15
Pushing stairs up to the rear passenger door of a Boeing B737-800

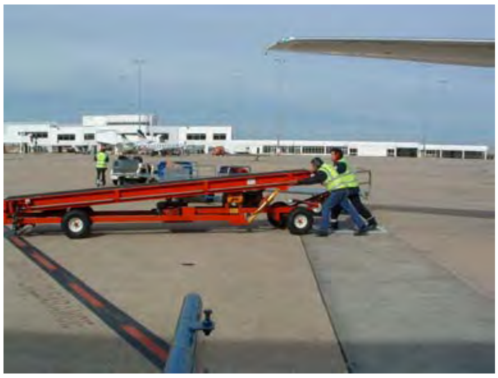

Figure 1.16
Pushing and pulling a belt loader, designed to be towed by a vehicle, away from the aircraft door

Manual handling also takes place at airports worldwide when aircraft loading equipment does not function as intended. Wide-body aircraft container loading systems are well known for being vulnerable to partial or total failure, particularly because some airlines appear not to afford the same maintenance priority to the baggage systems as they do to other, more flight critical, aircraft systems. If the baggage systems function correctly, no manual handling is involved. However, when these systems malfunction or when a container jams in the aircraft or on a loading machine, the baggage handlers are usually required to push and/or pull to free the often fully loaded containers manually [see Figures 1.17 & 1.18].

Figure 1.17
Pushing a container in the baggage compartment of a B747-300

Figure 1.18
Manually pushing a pallet of cargo off a pallet trailer

Other Relevant Features of Baggage Handlers' Work

The Nature of Baggage and Cargo

During the course of an average work shift, at any major airport, baggage handlers load and unload many flights with each person working on the loading and unloading of as many as six or eight flights. In addition, each worker would handle up to 100 items of baggage or cargo, or sometimes even more, per flight.

Passenger baggage and cargo varies greatly in size, weight and shape. Baggage handlers have to contend with lifting and stacking everything from small heavy and solid items like toolboxes, to large floppy items, like mailbags and awkward or bulky things such as bicycles, wheelchairs, surfboards and large heavy suitcases. In regard to cargo, on a daily basis, there are many items which can be problematic for baggage handlers. They commonly include things like carpet rolls, heavy machinery, spares parts including large, very heavy and awkward parts such as replacement light aircraft engines, spare aircraft wheel and tyre assemblies, even motorcycles. Generally, across the industry, if an item will fit in an aircraft compartment and the shipper can afford the airfreight rates, then it may be, and does get carried in aircraft, particularly when there is an urgent need for the items to be at their destination. Baggage handlers routinely have to contend with manually handling all these awkward and/or heavy cargo items, especially in cases where they're being sent to destination airports not serviced by containerized aircraft so that the items have to be bulk loaded into narrow-body aircraft.

Time Pressure

Baggage handlers often work with the added pressure of meeting stringent deadlines. It is well known that airlines are fiercely competitive and all have very strong "on-time" performance cultures. There is always pressure on baggage handlers to ensure the aircraft are loaded by the scheduled departure times and all airlines have administrative systems in place to ensure that on-time departures occur as often as possible. Largely driven by customer expectation, on-time performance is a key-performance measure of airlines the world over and everyone associated with the ground handling of aircraft are continually reminded of the issue (see for example *AWA (2005)* and *SAA (2005)*). In America, airlines' on-time performance is institutionalised to such an extent that the performance of all the major airlines is tracked and reported on the internet by the US Bureau of Transportation Statistics (*BTS (2005)*).

When operations are running smoothly, on-time performance is not a major issue for baggage handlers. However, operations frequently go awry, due to such factors as aircraft unserviceabilities, the failure of handling equipment, poor weather causing flight delays, or processing delays occurring in the terminal perhaps because of an unexpected large influx of passengers. Such time pressure on baggage handlers can become a major issue as staff attempt to minimise passengers' delays and hurry the baggage handling and aircraft loading work.

Another frequent cause of time pressure on baggage handlers has arisen from passengers checking-in for flights at the last-minute. Due to security rules, the passengers' baggage has to be loaded onto the same aircraft on which they travel. In many of these cases, the time pressure on baggage handlers arises because an on-schedule flight departure usually remains the expectation of both the airline and the passengers concerned.

Such time pressure can be a significant additional stressor on baggage handlers who often respond by attempting to carry out the baggage handling and other loading activities in the shortest possible time.

Baggage Handling: One of the Last Bastions of Heavy Manual Work

There is no doubt that on a global scale, baggage handling involves a significant manual handling problem, day in and day out.

The literature indicates that probably only in underground mining operations, do workers today face similar high daily manual workloads and experience similar high rates of back injury. *Stewart et al (2004)* in a review of materials handling injuries in underground coal mines in USA between 1998 and 2002 described the work in a way to which every airline baggage handler would immediately relate:

> "*Materials handling tasks involve pulling, hanging, pushing and lifting of objects of different weights, shapes, and sizes[4]. Hundreds of these tasks are performed in underground coal mines each day, and often supplies are handled two or three times before the end use*".

Patton, Stewart and Clark (2001) also reported that back injuries in underground mines were also a major safety problem for the industry, second only to roof collapse injuries and that…"*a significant percentage of back injuries is the result of lifting and pulling activities associated with materials handling*" which are often "*done in confined areas*" and "*without assistance*".

In these respects, the similarities of the manual handling related problems in airline baggage handling and underground mining are remarkable. In few other working environments are workers principally employed for their physical load shifting capability and routinely face such a high physical workload demand. Yet, manual handling related back injuries remain one of the major OH&S challenges to be solved in the 21st century.

1.2 BACK INJURIES: A MAJOR OH&S PROBLEM

Manual Handling: The Core Issue

Of all types of injuries that occur in the workplace, injuries related to manual handling have consistently been reported to be the most common worldwide.

Briggs (1995)) reported that 62% of workers compensation claims lodged at Boeing, one of the world's largest employers, were the result of manual handling injuries that cost US$345 million in 1994. The United States Bureau of Labour Relations Statistics reported that 62% of all workplace illness cases in the United States in 1995 were the result of repetitive manual handling trauma (*NIOSH (1997)*[1]). Also, in the United Kingdom, the Health and Safety Executive estimated that in 1995 alone, over 600,000 people in the UK reported a work-related musculoskeletal disorder that had been caused by manual handling activity (*HSE (1998)*). Again in 1999, the US Occupational Safety and Health Administration (OSHA) reported that musculoskeletal disorders due to manual handling accounted for one third of all occupational injuries and illnesses reported by employers in USA every year, and the lost work day musculoskeletal disorder rate for manual handling occupations in 1996 was 42.4 per 1000 employees *(OSHA (1999)*). More recently, *Davies et al (2003)*, in a UK study of 1504 people that were injured at work and required treatment at Merseyside Hospital, found that 40% of the injuries were the result of manual handling and that one in five of the manual handling injuries resulted in more than one month's absence from work.

Similarly, in Australia in 1993-94, a third of all compensated, work-related, injury and disease cases were the result of manual handling (*Foley (1996)*). In Western Australia, in the period July 1994 to June 1995, 30% of all lost time injuries, the largest single category, were manual handling injuries which cost $US 1.4 million per day (*MHC (1998)*). In 2005, the National Occupational Health and Safety Commission reported that:

> *"between June 1997 and June 2003, manual handling at work resulted in 366,275 compensation claims in Australia, or 41.5% of all compensation claims for that period, with a direct cost – not counting indirect impacts, including long term impacts on the victims' quality of life – of $7.126 billion"* (*NOHSC (2005)*).

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[4] "Hanging" in this context refers to hanging heavy power and other services cables and hoses from the roof of the mine, a task involving lifting the cables and hoses over head and clipping them to mesh and other fixtures attached to the mine roof.

Back Injuries: The Most Prevalent of Manual Handling Injuries

Of all types of injuries resulting from manual handling, back injuries have been reported consistently as being the most common and the most costly.

A Problem on a Global Scale

The literature abounds with reports of high back injury occurrence frequencies around the world. Compensation data from many industrialised countries showed manual handling injuries generally, and manual handling related back injuries specifically, as their most prevalent workplace injury problem. While it is difficult to accurately compare data from one country to another due to different approaches the various governments have to workers compensation, such as different minimum thresholds of injury severity to qualify for compensation, different reporting criteria, different injury classification methods and the many varied methods used for reporting accident frequency, the consistent theme of high back injury occurrence rates within the various jurisdictions suggested the problem remained an unchecked worldwide industrial epidemic.

In 1981, the USA National Institute for Occupational Safety and Health (NIOSH) reported that 35% of workers compensation claims in USA were related to back injuries (*NIOSH (1981)*). In 1987 back injuries accounted for 27% of all lost time compensation claims in Ontario Canada (*WCB (1988)*) and in 1989, the US Occupational Safety and Health Agency (OSHA) reported that a quarter of all compensation indemnity claims in USA involved back injuries costing billions of dollars in addition to the pain and suffering borne by the employees. OSHA indicated that more than one million workers in the USA suffered back injuries each year, that back injuries accounted for one in every five workplace injuries or illnesses and that three out of four workplace back injuries occurred while the employees were involved in lifting tasks (*OSHA (1989)*).

Damlund et al (1982) in a Danish study of 157 workers, who had retired early, found that 40% of the retirees reported low back pain as one of their reasons for early retirement. *Stubbs (1986)* in a report of a study of the nursing profession in England, and, *Saraste (1993)*, in a study of Swedish male workers with back ailments, both suggested that 80% of workers experienced lower back ailments during their working life.

In 1994, Jensen reported that 31 million Americans have low back pain at any given time with the medical care cost exceeding $US 8 billion every year (*Jensen et al (1994)*). *Bernard (Ed) (1997)* reported that 60% of lost time injuries due to manual handling in the United States in 1994, were back injuries which, according to *NIOSH (1994)*[1], cost over $US 20 Billion and accounted for 20% of all injuries and illnesses in USA workplaces that year.

In Hong Kong, *Yu T. et al (1984)* found that 60% of workers, in a 12 year study of Chinese workers, suffered from low back pain at work.

In New Zealand in 1993-94, 14,644 of 120,893 claims were back claims costing nearly NZ$ 34 million (*ACC (1998)*). In 1994-95, the number of new back injury claims in New Zealand rose to 17,720 costing nearly $NZ 43 million and in 1995-96 there were 17,216 new back claims costing $NZ41.6 million. The ACC also reported that in the same three years, the additional number and costs of *ongoing* back injury claims were: 1993/94: 6199 claims costing $NZ 37 million, 1994/95: 8268 claims costing $NZ60 million, and 1995/96: 21,710 claims costing $NZ170 million. In New Zealand these back claims represented the largest single cost to the social insurer and the number of claims and their associated costs were still steadily increasing. Half of all the back injury claims and the costs were work-related, according to the ACC.

In Australia, the situation seems to have been similar to elsewhere in the world. In 1994, *Wissenden and Condon (1994)* reported that back injuries accounted for more than 25% of work related injuries and cost over $1 billion per year in Victoria, and while many people recovered quite quickly, some became severely disabled and never returned to work. *Foley (1996)* elevated these figures slightly by suggesting that in Australia in 1993-94, 31% of compensated work-related injury and disease cases were the result of manual lifting, carrying and/or handling objects and that sprains and strains to the joints and muscles of the back accounted for 49.5% of those manual handling injuries.

Similar figures were reported by the Victorian Health and Safety Organisation in 1995. They reported that back injuries were the most serious injury type suffered by the claimants in 25% of workers compensation claims lodged in Victoria in the period 1992 to 1994 (*Health and Safety Organisation (1995)*). Also, back injuries were reported to be 30% of all New South Wales workplace injuries in the period 1993 to 1995 (W*orkcover New South Wales (1996)*.

More recently, the Australian Bureau of Statistics (ABS) reported in 2002 that back injuries accounted for 25% of non-fatal compensated injuries across Australia in the year 1999-2000 that resulted in 10 or more days off work (*ABS (2002)*). This percentage remained relatively constant the following year since, in 2003, NOHSC confirmed that in the period July 2001 to June 2003, 24.9 % of the 138,810 new workers compensation claims in Australia were back injuries and that 17% of all the new claims were injuries to the lower back (*NOHSC (2003)*).

A Problem for Companies

Occupational back injuries have clearly been an ongoing problem for national economies globally. They have also been a problem for corporations having a substantial impact on their profitability. In addition to the direct costs such as insurance premiums and medical fees, back injury cases have cost companies significantly under common law litigation. For example, *CCH (1995)* reported that two back injury cases heard in the Supreme Court of Queensland, where the employers had been found negligent for requiring their respective employees to lift weights beyond the reasonable capacity of an ordinary male, found in favour of the injured employees and awarded damages in the order of $399,000 and $450,000, respectively.

A Problem for Workers

Manual handling injuries also have a significant cost to the persons injured. The injuries have a substantial negative impact on quality of life and often shorten the persons' working lives. *Wissenden & Conden (1994)* suggested:

> "*Some people recover quite quickly and are still able to return to their work. However, others become so severely disabled with back pain that they are never able to return to work again".* This was supported by *Davies et al (2003)* who found that a fifth of people who suffered manual handling injuries required more than a month's absence from work and that around one in sixty people who suffered a manual handling injury, permanently left the workforce.

ACC (1998) also reported that those people in the more physically demanding jobs in New Zealand were less able to continue working after a back injury and may also have had to leave their employment. *OSHA (1999)* agreed with this and suggested that manual handling of heavy objects exposed employees to high forces that usually had the greatest impact on the back resulting in the most severe injuries.

In 2001, the leading USA medical technology company Medtronic Inc. (*Medtronic (2001)*), suggested that chronic pain seriously affected the quality of life, was unrelenting and demoralizing, and that people with chronic pain often could not work and their families and social lives deteriorated to the point where their total preoccupation with the pain caused irritability and depression. Medtronic further accounted that the psychosocial effects of chronic pain included the loss of employment income, depression, fear, anxiety, sleep disorders, marital dysfunction and feelings of personal isolation.

More recently in 2006, Professor Alan Hedge of Cornell University suggested in a literature review paper that "*low back pain was second only to upper respiratory tract infections as a cause of absence from work*" and the total annual cost of back pain in the USA had risen to US$56 billion, (*Hedge (2006)*).

The evidence is clear that worldwide, back injuries due to manual handling have for a significant period been an area of consistently poor industry performance. The injury rates continue unabated. There is little doubt there is a need to rethink the back injury prevention strategies applied in the past. In the face of the evidence, those strategies have not been effective in stemming the back injury tide.

A Summary of Back Injury Aetiology

There is a plethora of literature linking mechanical body loading scenarios to most parts of the body. Workplace manual handling has been linked to musculoskeletal injuries to the hands and arms, torso, hips and legs (see for example *NIOSH (1997*[3]*)*, *Gregory (1998) and Burgess-Limerick (2003)*), the neck (for example *Bullock (1999), Retsas (2000), Burgess-Limerick (2003) and McPhee (2004))*, the shoulders (for example *Egeskov (1992) and Hagberg (1996))* and the back (for example *Greenough and Fraser (1994), Gudavalli and Triano (1997), ACC (1998), Abbott (2002), McGill (2002), Burgess-Limerick (2003) and Croft (2004)*).

Furthermore, the literature overwhelmingly shows that musculoskeletal injuries have involved damage to most physical body structures including bones, tendons, muscles, joints, ligaments, nerves, blood vessels and other soft tissues *(*see for example *Hales and Bertsche (1992), ANSI (1994), Alberta (2000), Burgess-Limerick (2003),* and *ASCC (2006))*.

Most authors agree that the majority of back injuries involve the spine. The spine provides the human body with structure to support and stabilise the other organs while providing a degree of flexibility and mobility to the torso. It also provides structural protection to the spinal cord.

There are many texts available dedicated to the anatomy of the spine including the definitive anatomical text *Gray's Anatomy* (see *Gray 2004)*), and while a detailed description of the anatomy of the spine is beyond the scope of this study, a more simplistic understanding is necessary to place the manual handling risk related back injury factors into context.

As *Gray (2004)* describes, the spine has seven cervical, twelve thoracic, five lumbar, five sacral and five coccygeal vertebrae, the back bones. However, in relation to the issue of back injury and back pain, the focus needed to be on the lumbar and to a lesser degree the lower thoracic areas of the spine, since most authors agree that injuries to the lower back tend to be the most prevalent and costly (see for example *McGill (2002)*, *NOHSC (2003)* and *Hedge (2006)*).

The lumbar and thoracic vertebrae are separated by intervertebral discs which are bonded to the adjacent vertebrae, top and bottom.

Most early studies into low back disorders (for example *Farfan (1973)* and *Nachemson (1975)*) and some more recent authors (eg *OHSB (2006)*) suggested the intervertebral discs help absorb any unusual shock loads or sudden compression, acting as “shock absorbers” for the spine. However, *McGill (2002)* suggested a more complex interaction between the disc and the surrounding bone of the vertebrae which provide the energy absorption function. Regardless, all the authors agree that back injury occurs when the applied load on the back surpasses the back structures’ ability to absorb that load and this applied not only to the vertebrae and discs, but also to the myriad of muscles, tendons, ligaments, and other soft tissue of the back, albeit injuries to these soft tissues tended to be less severe, less debilitating and of shorter recovery duration than injuries to the vertebral discs.

One Time Overload Vs Accumulative Wear and Tear

Review of the literature suggests two schools of thought exist about the influence on injury causation due to exposure to a one time heavy load which generated forces in the back beyond the persons’ injury tolerance, versus the accumulative effect of multiple exposures, to perhaps lower loads, over a period of time. In the text on low back disorders, *McGill (2002)* suggested that: "*Very few back injuries, however, result from a single event*", rather he suggested the more common injury causation scenario was via accumulative trauma that leads up to a "*culminating event of a back injury*". McGill also expressed concern that because the culminating event was often falsely assumed to be the cause, only that factor was addressed and other opportunities to address the "*real*" causes may then have been missed.

On the contrary, *Patton, Stewart and Clark (2001)*, in their review of manual handling injuries in underground mines, felt that most injuries related to materials handling were the result of situations occurring "*where for reasons of expediency and in the absence of help, the worker tried to lift materials or handle equipment that were too heavy*".

However, it seems reasonable to assume that both these scenarios could co-exist and both accumulative wear and tear as well as overload due to heavy loads above tolerance levels need to be considered if back injury risk is to be effectively controlled in future.

Back Injury Risk Factors

There was a high degree of consensus in the literature concerning factors which affect the risk of manual handling related back injuries.

<u>Lifting Posture, Reach and Disc Compression Forces</u>

McGill (2002) suggested that during lifting, muscle and ligament forces required to support the lifting posture and facilitate movement imposed "*mammoth*" loads on the spine. A man lifting a 27kg object with the hands and using a squat lifting posture would experience a compressive load on the spine of around 7 kN, sufficient load to cause injury in very weak spines according to McGill, while an average young healthy man could probably tolerate 12 to 15 kN. As *McGill (2002)* went on to suggest, this was the principle reason why lifting technique was so important to reduce forces on the low back due to load moment and to reduce the risk of injury. The greater the horizontal distance between the load in the hands and the spine, the greater the resultant force exerted on the structure of the back for any given load mass. Indeed, this phenomenon stems directly from the basic physics of levers (see for example *Cucinotta (2002)* and *Finck (2004)*). Accordingly, keeping the load as close as possible to the spine has been a concept long accepted as an effective back injury prevention method (see also *Lindh (1980), Marras et al (1995), Marras et al (1999)*, *Marras (2000), UOM (2004)* and *McPhee (2004)*).

<u>Lifting Posture Influencing Trunk Rotation and Spinal Shear</u>

Hedge (2006) in a summary paper on back stress concurred with these other authors and acknowledged "*Compressive forces exert the major influence on low back injury risks*". However, Hedge added that axial rotation of the trunk causing "*torsional deformation of the intervertebral disc*" and lateral bending causing "*asymmetric compression of the intervertebral disc*" were also back injury risk factors. Indeed, McGill (2002) concurred with this and also implicated trunk flexion in the injury to spinal ligaments:

> "*Damage to spinal ligaments may occur if high loads are encountered in extreme postures, for example, a position of extreme trunk flexion places the posterior longitudinal ligaments and interspinous ligaments at high risk if high forces are applied.*

Nearly all authors acknowledged awkward body posture as being a key back injury risk factor for the reasons described here. Indeed the notion is so well accepted that many government regulators have published criteria on the matter. For example, in 2000 the Government of Alberta, Canada, in a six part review of musculoskeletal injuries, published a table of risk factors to be used to determine if a manual handling task represented a potential injury concern (*Alberta (2000)*). Awkward body posture was at the top of the list, as Table 1.1 shows. High hand forces when gripping and pinching with the fingers, repeated impact using the hand or knee and hand-arm vibration were also listed, although these factors seem unlikely to be exhibited in relation to airline baggage handling.

Table 1.1
Physical Risk Factors for Assessing Manual Handling Tasks
(from *Alberta (2000)*)

	Physical Risk Factor	Duration
Awkward Body Positions	1) Working with the hand(s) above the head, or the elbow(s) above the shoulder. 2) Working with the neck or back bent more that 30 degrees (without support and without the ability to change posture). 3) Squatting 4) Kneeling	1) More than 2 hours total per day. 2) More than 2 hours total per day 3) More than 2 hours total per day 4) More than 2 hours total per day
High Hand Force	1) Pinching an unsupported object(s) weighing 500 grams or more (2 lbs) per hand, or pinching with a force of 180 Newtons or more (4 lbs) per hand (comparable to pinching half a ream of paper). 2) Gripping an unsupported object(s) weighing 4.5kg or more (10 lbs) per hand, or gripping with a force of 340 Newtons or more (10 lbs) per hand (comparable to clamping light duty automotive jumper cables onto a battery).	1) More than 2 hours total per day 2) More than 2 hours total per day
Highly repetitive motion	1) Repeating the same motion with the neck, shoulders, elbows, wrists, or hands (excluding keying activities) with little or no variation every few seconds 2) Performing intensive keying	1) More than 2 hours total per day 2) More than 2 hours total per day
Repeated impact	1) Using the hand (heel or base of palm) or knee as a hammer more than 10 times per hour.	1) More than 2 hours total per day
Heavy, frequent or awkward lifting	1) Lifting objects weighing more than: a. 34kg (75lbs) once per day or b. 25kg (55lbs) more than 10 times per day 2) Lifting objects weighing more than 4.5kg (10lbs) if done more than twice per minute 3) Lifting objects weighing more than 11.4kg (25lbs) above the shoulders, below the knees, or at arms length more than 25 times per day.	2) More than 2 hours total per day
Moderate to high hand-arm vibration	1) Using impact wrenches, carpet strippers, chain saws, percussive tools such as jackhammers, scalers or riveting or chipping hammers, or other hand tools that typically have high vibration levels. 2) Using grinders, sanders, jigsaws, or other hand tools that typically have moderate vibration levels (Employers may assume that hand tools vibrating less than 2.5 m/g2, eight-hour equivalent are not covered).	1) More than 30 minutes total per day 2) More than 2 hours total per day

<u>Lifting Heavy Objects</u>

Perhaps not surprisingly, many authors (see for example *Alberta (2000), McGill (2002), Burgess-Limerick (2003) and UOM (2004)*) have identified lifting heavy objects as a significant manual handling injury risk factor. Clearly, if compressive forces on the spine have been identified as a concern, then together with lifting technique and posture, the factors influencing load moment and propensity for injury, the weight of the object being lifted will also be a major manual handling injury concern.

The Effect of Restricted Work Spaces

In their empirical laboratory study of effects of restricted vertical workspace on the spinal load of workers simulating lifting cable and attaching it the ceiling of a mine, *Gallagher et al (2001)* found that there was an almost linear increase in the peak moment on the lumbar spine as the vertical workspace reduced. Peak load moment at the L5S1 lumbar disc was measured using the Ariel Performance Analysis System[5] at 204 Nm when working in a workspace of 2.1 metres vertical height using a standing posture, increasing by nearly 50% to 307 Nm when working using a kneeling posture in a workspace with a vertical height of 1.2 metres.

These findings of Gallagher et al clearly also have implications for airline baggage handler back injury risk. Airline baggage handlers also carry out heavy manual handling work in spaces with restricted vertical dimensions and with sometimes awkward lifting postures.

Task Frequency, Repetition and Duration

Many authors agree that task frequency, repetition and task duration are musculoskeletal injury risk factors. Manual handling tasks which necessitate repeated movements affect the soft tissues of the body over time. When the same groups of muscles, tendons and ligaments are used repeatedly without rest, they begin to ache at the onset of distress. If the tissues involved are not rested, a gradual decline in physical capability to handle the load occurs when muscles begin to tire and cramp. When this occurs, other adjacent muscles not usually intended for the work attempt to take over the load and they too more quickly tire leading to the possibility of sprain and strain injuries. *McGill (2002)* summarised the phenomenon by suggesting that repeated activities

[5] Details on the Ariel Performance Analysis System, a non-invasive computerised postural measurement system, can be found at http://www.arielnet.com/main/adv-04.html.

led to tissue fatigue and reduced failure tolerance, "*leading to failure on the Nth repetition of load*". Clearly, the higher the frequency of repeated activity, the greater will be the number of repetitions for any period of time. The longer such activities continued without opportunity for rest, the higher will be the risk of injury.

Tolerance to Load: Age, gender, previous injuries and fitness

In his issues paper on force and weight limits in the area of manual handing, *Burgess-Limerick (2003)* acknowledged the range of factors mentioned here that have impact on spinal loading. However, Burgess-Limerick also suggested tissue tolerance to load was another related injury risk factor which varied "… *with age and sex*". *McPhee (2004)* succinctly summarised the effect of age on manual handling injury risk:

> "*Physical capacity decreases with increasing age. This is due to decreasing physiological capacity, often in association with the effects of musculo-skeletal disorders such as back, shoulder and knee injuries. Likewise sensory, perceptual and cognitive abilities decline, although these are not as obvious until the mid 50s.*"

Welch, Hunting and Nessel-Stephens (1999), in a review of musculoskeletal injuries in construction workers, found also that older workers were more likely to have longer lasting symptoms of injury than their younger counterparts.

In their literature review on the prevention of low back injuries, the New Zealand Accident Compensation Commission identified that nearly as many women as men submitted claims for compensation due to back injuries in the period 1995 to 1997 (*ACC (1998*) and:

> "*Females are making more claims, including back injury claims, than previously, but the percentage of back injury entitlement claims to total claims is about the same as for males…This change over the last 10 years could reflect the changing demographics of the workplace with*

> *more females working and working in traditionally male (eg heavy labour) occupations and industries*."

Pinder, Reid and Monnington (2001), in a literature review of musculoskeletal disorders experienced by brick layers, carpenters and plasterers in the United Kingdom, found that health research into the effect of gender in manual task intensive occupations was almost non existent. Indeed, in a low back pain research review paper, *Marras (2000)* reported that of 24 studies which attempted to associate gender as a low back pain risk factor, only eight percent established a relationship.

Not withstanding, *Jager et al (2001)* in a paper describing a model for defining the load on the lumbar spine, prescribed maximum compressive strength limits for the lumbar spine by age and gender, clearly showing gender difference in the area of back injury tolerance. Jager et al recommended the maximum compressive strength for 20 year old female lumbar spines to be around 1500 N less than that for males of the same age, reducing to a difference between the sexes of around 1000 N at age 40 and around 500 N at age 60.

In a prospective study of 679 university athletes, *Green et al (2000)*, found that a history of low back injury was the significant predictor for a follow up injury and athletes that reported a previous injury were at three times greater risk of a back injury occurring. Daltroy et al (1991) had similarly found a correlation between the occurrence of a back injury and having previously experienced a back injury. It seems logical that one of the outcomes of back injuries would be the weakening of the affected tissue and other problems of reduced back function and capability defined by *McGill (2002)* as "lingering deficits" which lasted years and increased the risk of a recurring injury through reduced load bearing capability.

Jayson (1996), in an opinion piece on work related back pain suggested:

> "*The principal risk factor for back pain is a past history of back pain. Those who have suffered back problems in the past are likely to experience further episodes in the future*"

There is a considerable weight of opinion in the literature that an individual's risk of musculoskeletal injury from manual handling is reduced by maintaining a good level of fitness and exercise. However, papers where this notion was tested appear non existent. In relation to low back injury propensity, *McGill (2002)* suggested there was "mounting evidence that aerobic exercise in both reducing the incidence of low back injury and treating back injury patients" and went on to argue "*Because the spine has a loading memory, a prior activity can modulate the biomechanics of the spine in a subsequent activity*". This suggests moderate back exercise may condition the spine for the subsequent manual handling activity and thereby improve spinal function and may impact on the risk of back injury.

1.3 HISTORY OF THE AIRLINE BAGGAGE HANDLER MANUAL HANDLING AND BACK INJURY PROBLEM

The manual handling methods employed by baggage handlers, the types of support equipment available to assist baggage handlers, the design of airports and that of many aircraft baggage compartments have changed very little from the start of airline operations in the 1920s to the end of the 20th century.

Figure 1.19 shows a Fokker F.VIII being loaded in 1926, Figure 1.20 shows baggage being loaded into a Douglas DC-3 aircraft in 1940, Figure 1.21 depicts workers loading baggage into a Lockheed L1049 in 1955 and Figure 1.22 shows baggage being loaded into a Boeing B737 in 2001. Although the aircraft, vehicle and clothing designs have changed noticeably over the 80 years, in these examples it is difficult to identify many differences in the manual handling activities being undertaken by baggage handlers.

Figure 1.19
Baggage handlers loading a Fokker F.VIII, 1926[6]

Figure 1.20
Baggage handlers loading a: Douglas DC-3, 1940[7]

Figure 1.21
Baggage handlers loading a Lockheed L1049, 1955[8]

Figure 1.22
Baggage handlers loading a Boeing B737-400, 2000

However, a review of the literature showed that injuries to airline baggage handlers have only become a concern relatively recently and comprehensive data on the magnitude of the problem had not really emerged until the second-last and last decades of the 20th Century. For example, *Lundgren, Soderqvist, Larsson and Jernberg (1988)* in an empirical study of injuries to Scandinavian Airlines System (SAS) baggage handlers at Stockholm airport, found that fifty two manual handling injuries had occurred in 1988, an average

[6] Photo courtesy N.V. Royal Netherlands Aircraft Factory Fokker
[7] Photo reproduced from Pearcy A.(1995).
[8] Scene from 35mm film "Song of the Clouds", Shell Film Unit, London (1959).

of one injury per week, cost a total of SEK 982,848 ($US178,600.00 approx[9]). Similarly, in a review of baggage handling injury claims at Qantas Melbourne Airport, *Grodek (1994)* reported that 42 separate injury claims occurred costing $A325, 000.00 in 1990, and *Gaber (1998)* in a review paper on baggage handler injuries at Frankfurt Airport, reported that 800 of the 4,500 baggage handlers working at Frankfurt Airport were absent every day due to manual handling injuries at a cost of $US500 per person per day or $US146 million per year. *Gaber* further reported that two thirds of these manual handling injuries were back injuries.

In fact, the problem of airline baggage handler back injuries first emerged in the late 1970's. A National Safety Council of America, Air Transport Executive (*ARTEX (1981)*) study of baggage handler injuries in nineteen major airlines, looked at the occurrence of baggage handler injuries in five different phases of the airline baggage handling operation: During baggage handling at check-in, in the baggage make-up rooms, during loading operations on aircraft parking aprons, while unloading on aircraft parking aprons, and "in baggage stacking operations inside aircraft". The *ARTEX* study captured data for one year, 1977.

In total, the *ARTEX* study found 1701 back injuries occurred in that one year in the participating airlines. There were 309 back injuries in 19 respondent airlines reported at check-in, 246 back injuries in baggage sorting rooms (12 airlines), 538 back injuries during loading on the ramp (12 airlines), 340 back injuries stacking inside aircraft (10 airlines), and 268 back injuries unloading on the ramp (10 airlines).

Although this study made no recommendations for addressing the baggage handler back injury problem, it showed clearly for the first time that repetitive baggage handling tasks exposed workers to significant injury risk and that back injuries were a wide-spread problem in the airline baggage handler workforce.

[9] Based on an approximate conversion rate of $US1.00 to SEK5.5 reported to have been effective in the late 1980s.

Since 1981, concern about injuries to baggage handlers has been growing within the industry. In 1987 in a review paper, *Jorgensen et al* found that the frequency of injuries, including the frequency of back injuries, to baggage handlers at Copenhagen, Oslo and Stockholm airports were steadily increasing *(Jorgensen et al (1987))*. *Queinnec and Daniellou (1991)*, reporting on a retrospective study of the work activities and perceived levels of musculoskeletal stress of baggage handlers, found the highest number of musculoskeletal complaints related to injuries of the lower back. *Holt (1993)* found that 75% of the 61 baggage handlers who responded to a wellness survey at Wellington Airport, out of the total of 80 baggage handlers employed at Wellington, had experienced aches and pains of the lower back.

In a 1996 position paper, the UK Health and Safety Executive reported that:

> ”*At airports, the single greatest cause of injuries reported to the Health and Safety Executive (HSE) is from manual handling, mostly from baggage handling*” *(HSE (1996).*

More recently, the HSE *(HSE (2003))* reported that 50% of all injuries reported at UK airports were musculoskeletal disorders from the handling of baggage and cargo. More recently, *Culvenor (2004)* in a review of baggage handling injured at Qantas Airports Division, found that 25%.of all injury compensation claims, over the five years to June 2003, related to baggage handling.

Clearly, the problem of injuries to airline baggage handlers remains to be solved.

The Literature Concerning the Risk Factors Associated with Manual Handling of Airline Baggage

The Working Environment of Baggage Handlers

With regard to the working environment of baggage handlers, several authors, *ARTEX (1981), Stălhammar et al (1986), Jorgensen et al (1987), Evans and Pratt (1994), Hogwood (1996) and Berubé (1996),* agreed that poor ergonomic design of narrow body aircraft cargo compartments placed serious limitations on baggage handler working postures and significantly increased the risk of injury.

Ruckert, Rohmert and Pressel in a two year longitudinal study of manual lifting and handling tasks of forty-four baggage handlers (*Ruckert, Rohmert and Pressel (1992)*) found that baggage handling was a special manual handling case because it takes place in height-restricted workplaces in aircraft baggage compartments that:

> *"cause the workers to adopt ergonomically unfavourable working postures, causing strain in the postural and locomotor apparatus*".

They also measured increased average working heart rates and 37% higher L5/S1[10] disc compressive forces during baggage loading in the restricted height aircraft baggage compartments compared to larger aircraft and they found that most complaints of the baggage handlers were related to problems with their backs. *Stălhammar et al (1991)* in a laboratory study of baggage handlers loading a mock-up DC9 baggage compartment, best summed up the ergonomic problems of the narrow-body baggage compartment with the statement:

> *"At airports materials handling in aircraft luggage compartments involves physical work performed mainly manually in uncomfortable working postures leading to an increased musculoskeletal stress and complaints".*

In a study of baggage handlers that involved observation of the loading of Boeing B737 narrow-body aircraft at Australian Airlines, *Egeskov* (1992) found 85% of all injuries to the baggage handlers were muscle stress due to manual handling of baggage and cargo and that manual handling work inside the baggage compartments represented the greatest risks:

The findings of these authors are perhaps not surprising when the significantly restricted working environments of narrow-body aircraft

[10] The vertebral disc between the 5th lumbar vertebrae and the 1st sacral vertebrae

baggage compartments, with floor to ceiling heights as low as only 81cm and up to only 112cm, are considered (see Figure 1.23).

The baggage compartments of these narrow-body aircraft, and the similar bulk holds of wide-body aircraft, are little more than spaces below the passenger cabin floor[11], in which the baggage and cargo must be stacked in bulk, and manual handling is the only option available to workers for the loading and unloading of these compartments.

In the past there seems to have been some reluctance to tackle the poor ergonomic design of aircraft baggage compartments. In 1993, in a report to Qantas Airways providing opinion regarding the loading of wide-body aircraft bulk holds, *Kegreiss and West* identified pushing and pulling baggage at extreme ranges of movement and twisting of the spine in the "*inadequate and confined spaces*" of baggage compartments as a significant risk to baggage handlers, but went on to suggest that the "*aircraft cannot be altered*" (*Kegreiss and West (1993).* In 1996, *Briggs* opinion was similar, that:

> "*there will have to be airline industry consensus before the aircraft manufacturers will carry out design changes to their aircraft" (Briggs (1996)).*

It seemed that the aircraft manufacturers required more evidence of the need for change than that offered by the ongoing baggage handler injury rates and associated costs.

Hoffman (1995) observed the working posture of baggage handlers working outside the cargo compartment door during loading and unloading of Qantas B737 aircraft at Sydney Domestic Terminal. *Hoffman* found that baggage handler postures were stooped with bent backs during unloading, because the belt loaders used at the aircraft doorway were often set too low at the operator end for the stature of the people involved, and the baggage handlers did not

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[11] In small commuter aircraft, the space for stowage of baggage and cargo is often behind or in front of the passenger compartment, due to the smaller fuselage diameter.

move their legs but rather twisted their backs to shift the baggage from the conveyor to the trailers.

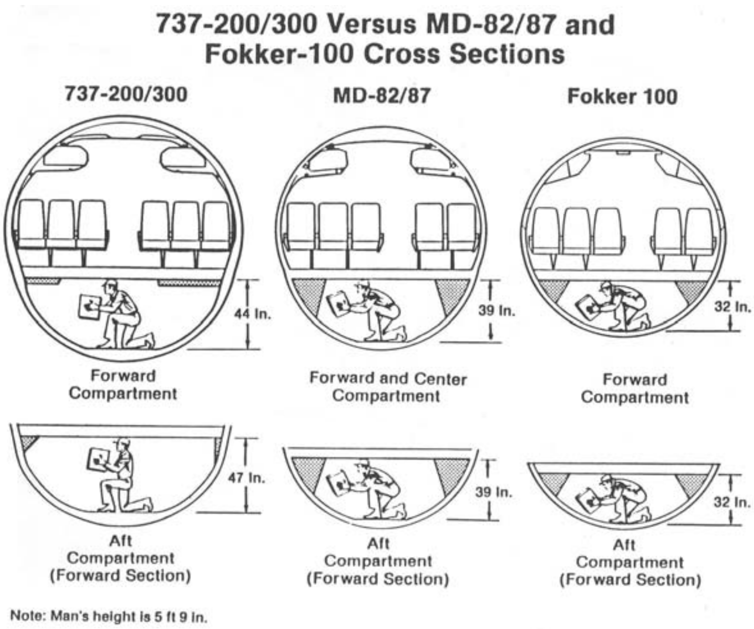


Figure 1.23
Headroom in narrow-body aircraft baggage compartments: A comparison of three common aircraft[12]

By contrast, with regard to the baggage handlers tasked with taking the baggage off the belt loader inside the aircraft doorway and propelling it into the baggage compartment to the person stacking, *Egeskov (1992)* suggested that the risk was greater with:

> "*manual handling work inside the locker, but it was hard to associate the employee working at the top of the conveyor belt as the major one at risk*".

The Load: The Effect of Baggage Weight

Hoffman (1995) raised the issue of baggage weight as a significant injury factor, an issue which has also been brought to attention by several other authors such as *Berubé (1996)*, an ergonomic evaluation of baggage handling tasks at Toronto, which summarised the risk factors by comparison with

[12] Figure courtesy of Telair International Scandinavian Belly-Loading Company, Lund.

contemporary research and (*ARTEX (1981)*. Also, *Davis and Marras (2003)* in a laboratory study of trunk kinematics and spinal loading that looked at the effects of lifting rates, load weight, load position and task asymmetry, found that the weight of the load was the "*most important factor*" when controlling spinal compression forces when lifting, clearly indicating its importance in baggage handler back injury causation and prevention.

In a 1991 survey of musculoskeletal complaints amongst nineteen volunteer baggage handlers, *Stălhammar et al (1991))*, reported that each of the nineteen baggage handlers were observed to lift an average of over 10 tonnes of baggage during each work shift. More recently, *Culvenor (2004)*, in a study of the daily workload of thirty-nine Qantas Airways baggage handlers, found the average weight handled per person, in an average 7.1 hour shift, was 8 tonnes. It was, perhaps, not surprising then that *Culvenor* also found that one quarter of Qantas' Airports Division's fifty most expensive injury compensation cases, over the five years to June 2003, were related to heavy baggage which cost the airline over $A2.5 million.

With regard to the weight of individual baggage items handled, *Darby (1994)* in a retrospective study of baggage loading and unloading at Auckland International Airport, found that 60kg bags were common on flights to and from the South Pacific and *BBC (2004)* reported that baggage handlers at Heathrow have been required to lift items up to 70kg.

The total weight of baggage lifted by airline baggage handlers and the weight of individual items lifted, was clearly a back injury causation factor for the workforce.

Some Solutions Offered in the Literature

To put the range of possible solutions to the baggage handling problem into context, the modern hazard control theory known as the Hierarchy of Hazard Control has to be considered.

Indeed, in many jurisdictions there is a statutory obligation to apply the principles whenever hazard control decisions are being made.

The Hierarchy of Hazard Control theory suggests that injury mitigation methods fall into a hierarchy of diminishing effectiveness (see for example opinions from *DOL (1990), Dell (1999), CSU (2005) and WorkCover NSW (2007)*), with solutions which entirely eliminate the hazard from the workplace the most effective solutions, at the top of the Hierarchy, as Table 1.2 shows.

Clearly, it is not possible for workers to be injured by a hazard if that hazard is not present in the workplace. Accordingly, elimination is the most effective method of hazard control. Albeit, many hazards in the workplace are required as part of the operational function and cannot be eliminated without significant effect on production, a factor which most often precludes the use of elimination as a solution.

Table 1.2
Hierarchy of Hazard Control
(from *CSU (2005)*)

Hierarchy	**Explanation**
Elimination	Eliminate the risk by removing the hazard.
Substitution	Substitute less hazardous materials, equipment, processes or substances.
Engineering Controls	Make structural changes to the work environment, work systems, tools or equipment to make them safer. Use mechanical aids or manual handling devices. Enclose or isolate the hazard through the use of guards or remote handling techniques. Provide local or general exhaust ventilation.
Administrative Controls	Establish appropriate administrative procedures such as policies, guidelines, standard operating procedures (SOPs), registers, work permits, signage, job rotation, job timing, routine maintenance and housekeeping. Provide training on hazards and correct work procedures. Keep training registers and individual training records. Supervise for compliance with set standards.
Personal Protective Equipment (PPE)	Provide correctly fitted and properly maintained personal protective equipment (PPE), and/ or protective clothing and the training in its use.

Replacing a hazardous item of plant, chemical or process with another less dangerous is the second most effective method of control in the Hierarchy. As with Elimination, the hazard removed from the site cannot cause harm in the workplace. However, the replacement item of plant, chemical or process will have inherent hazards which will themselves require control to prevent injury.

Under the Hierarchy theory, if it is not possible to eliminate or substitute the hazard, then it may be possible to alter the design to include methods of preventing the hazard from causing harm. Examples include fixed guards, barriers, enclosures and electronic interlocks. Mechanical aids for materials handling tasks, such as the belt loaders used by baggage handlers and the conveyor systems in the airport terminal, pneumatic and robotic manipulator arms, would be examples of engineering controls.

Administrative controls are less effective than elimination, substitution or engineering controls, due to the reliance on human performance to ensure effective administrative hazard control. Despite this apparent shortcoming, virtually all workplaces rely to some extent on administrative controls, in particular work procedures, training and supervision. In the baggage handling area, such interventions as lifting techniques, baggage weight limits, job rotation and two person lifting policies fall into the administrative control category.

The last and lowest level of control under the Hierarchy is the provision of personal protective equipment (PPE) to prevent those persons exposed to the hazard from being injured. As suggested by CSU (2005), this method of control "*does nothing to minimize or alter the original risk, and any failure of the PPE exposes the wearer to the full hazard potential*". Traditional worker PPE includes safety helmets, hearing protectors, goggles and protective clothing such as safety boots, high visibility vests, overalls and gloves. Baggage handlers often wear such protective equipment, save perhaps for the helmets and goggles. The back support belts worn by some baggage handlers are an example of personal protective equipment intended to reduce the risk of back injury. Although, as discussed later in this Thesis, there was a consensus in the literature that indicated back support belts may be ineffective as a hazard control measure even when properly worn and used by the individuals concerned.

In summary, based on the Hierarchy of Hazard Control theory, it would be expected then that solutions to the baggage handler back injury problem which involved elimination of the manual baggage handling hazards, effectively meaning elimination of the manual baggage handling tasks themselves, would be most effective. Solutions which substituted manual handling tasks with high musculoskeletal loading with ones with lower loading should be next most effective.

According to the Hierarchy of Hazard Control theory, solutions which influence the way the baggage handling work is carried out, such as altering baggage handler work practices and procedures, controlling lifting techniques, setting rules on baggage weight limits and those interventions which rely on compliance behaviours by the baggage handlers, are likely to amongst the least effective intervention measures.

Mechanization of Baggage Handling Tasks

In an opinion paper on the prevention of baggage handler injuries, Briggs (1996) suggested that there were:

> "*two approaches widely available for mechanizing the loading process to some degree for the standard body aircraft:*
>
> - *Air Cargo Equipment (ACE) Telescoping Baggage Cargo System*
> - *Sliding Carpet Loading System (Scandinavian Bellyloading Company)*

Manufacturers of both the above systems express that they provide advantages over the traditional 100% manual bulk loading process: a reduction in personnel injuries, reduction in manpower"[13]

Figure 1.24 shows the Scandinavian Belly Loading Company "*Sliding Carpet*" system and Figure 1.25 shows the *ACE* system.

These systems provide a moveable wall which can be positioned near the baggage compartment door so that one person can take the baggage from the belt loader in the doorway and stack the baggage against the moveable wall. When bags are stacked to the ceiling, the wall and bag stack are moved backwards and another stack of bags is then made. The stacking and wall moving cycles continue until the compartment is full of baggage.

The functional benefit of the Sliding Carpet system, which is similar to that of ACE, is depicted in Figure 1.26 that shows a baggage handler working alone within the forward baggage compartment and stacking baggage against the moveable bulkhead of the system, before activating the sliding carpet to move the bulkhead and baggage stack further into the compartment to make room for another stack adjacent to the doorway.

Figure 1.24
Telair Scandinavian Belly Loading, Sliding Carpet Loading System

Figure 1.25
Air Cargo Equipment (ACE) Telescoping Bin Loading System

[13] Boeing refer to narrow-body aircraft as "standard body aircraft"

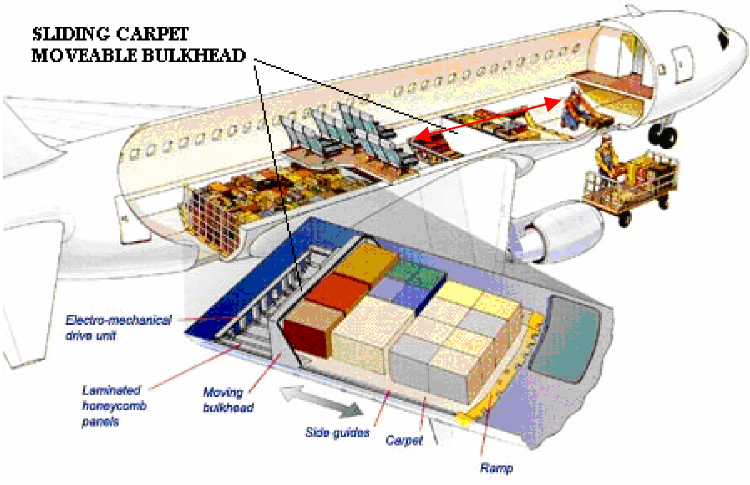


Figure 1.26
Functional diagram of the
Sliding Carpet Loading System[14]

Both these systems eliminate one baggage handling task, that is the need for baggage to be shifted manually down the length of the cargo compartment.

Installation of these systems is steadily growing globally. *G&G Aviation (2005)* reported that 400 *Sliding Carpet* units have been installed[15] to date and that an additional 400 units were on order with manufacturer, Telair.

Some authors support the systems' manufacturers' contention *(see Telair (2005))* that they reduce baggage handler injuries. In a 1986 technical paper on the development of a similar Sliding Carpet system for installation in Fokker 100 aircraft, aircraft manufacturer Fokker predicted "*the moving belt system substantially reduces the physical load of the baggage loaders*" and *"the workload reduction results from the deletion of the transportation and stowing in the compartment*" *(Fokker (1986))*. Accordingly, Fokker did not base their "substantial" reduction claim on any systematic analysis of baggage handler workload, but rather on the basis that the system eliminated the need to manually transport the baggage and stack it within the baggage compartment and all its associated workload. It also ignored the fact that the

---

14 Diagram courtesy of Telair International, http://www.telair.com/narrowBody_slidingCarpet.html. Red arrow depicts direction of movement of the Sliding carpet moveable bulkhead.

15 Typically two Sliding Carpet units are installed in each aircraft, suggesting approximately 200 aircraft have been fitted with Sliding Carpet.

baggage stacking task was still necessary, although it would take place in the doorway of the aircraft when a system was fitted, rather than within the baggage compartment. However, Fokker conceded that *"a small increase in workload is expected from the loading of the compartment*" with a system installed. Although they did not attempt to quantify this "small" workload increase, Fokker acknowledged it was expected to be more physically demanding to load baggage into the system than was the case loading baggage into an aircraft without a system fitted.

Perhaps the most encouraging study of the effect of these systems was the in service evaluation conducted by Scandinavian airline, Braathens SAFE after all seventeen of their B737 aircraft had operated for one year with Sliding Carpet systems installed (*Johansen (1995)*). Their review found a 25% reduction in baggage handler sick leave rates and a 3% reduction in the number of baggage handlers required in the loading and unloading operation. *Johansen* also reported that the airline measured no increase in aircraft fuel consumption due to the additional aircraft weight caused by the system and projected a $US 2 million cost saving over the first 3 years of operation of seventeen B737 aircraft with the system installed.

In another positive study pertaining to Sliding carpet, *Stokholm (1988)*, in an opinion survey of baggage handlers at Copenhagen Airport, found that of 218 respondents, 47% felt the "work loads on the back were less" when loading an SAS DC9 aircraft fitted with a trial *Sliding Carpet*, against 3%.who felt the workload increased. Although *Stokholm* did not comment on this, presumably the balance of 50% of baggage handlers did not feel strongly enough either way suggesting they probably felt on balance that the Sliding Carpet made no difference at all to loads on the back. Not-withstanding, *Stokholm* did suggest that over 90% of respondents felt that loading a DC9 aircraft fitted with *Sliding Carpet* was better than loading a DC9 without one.

In addition to these preliminary positive publications concerning Sliding Carpet systems, one author reported positive outcomes pertaining to the trial of an ACE system installed in an SAS DC9 aircraft. *Jorgensen et al (1987)* an opinion survey involving six baggage handlers who loaded and unloaded the

DC9 with the trial *ACE* loading system fitted, reported an 11% decrease in energy consumption by baggage handlers using the system, and a “marked” decrease in postural muscle strain of the shoulders and lower back. Such findings provided little more than to encourage further research, since the small number of subjects involved in the study, the small magnitude of the reported reduction in workload measures when using the system and the statistically limited opinion survey outcomes.

Furthermore, there are many authors (see for example *McGill (2002)* and *OHSB (2006)*) that suggest back pain is often the due to long term damage from constant manual handling activities and an immediate significant fall in back pain or injury rates for long term employees, such as reported by *Johansen (1995)* and *Jorgensen et al (1987)* should be treated with caution and more independent corroboration sought. This review of the literature has shown there are many potentially confounding issues.

It was apparent that when installed, both the in-plane systems discussed here, ACE and Sliding Carpet, require a baggage handler to manually stack the baggage in the baggage compartment, even though with the systems’ installed, the stacking activity took place within the compartment adjacent to the aircraft baggage compartment doorway rather than within the compartment way from the doorway.

No literature was found which assessed the residual injury risk to baggage handlers stacking baggage into these narrow-body aircraft systems. This void directly led to the development of the experimental design for Phase 4 of this study which endeavoured to measure the difference in risk to baggage handlers when using these systems to the risk involved in stacking baggage in the aircraft compartment without such systems fitted.

Some Earlier Research Focused on the Person: Manual Handling Training, Back Support Belts and Resting Supine

Smidt (1998) reported the results of a one year study into the benefits of both manual handling lifting technique training and back support belts as prevention methods for baggage handler back injuries at KLM Royal Dutch

Airlines (KLM). Two hundred and eighty two KLM baggage handlers participated in the study and were evenly divided into four groups. One group were provided with both manual handling lifting technique training and back support belts, one group received just the technique training, one received just the back support belts and a control group received neither the training nor the back supports. The *Smid* study found that neither the training nor the back support belts had an effect on the baggage handlers' back injury outcomes.

The findings of *Smidt (1998)* are consistent with those an earlier similar study by *Reddell et al (1992)* involving 642 baggage handlers at American Airlines. The baggage handlers were also evenly divided into four groups with one group provided with both manual handling lifting technique training and back belts, one group received just the technique training, one received just the back belts and a control group received neither the training nor the back belts. Like *Smid*, the *Reddell et al* study found that neither the training nor the back support belts had an effect on baggage handlers' back injuries.

In relation to the application of back belts as a back injury prevention measure, these studies of airline baggage handlers were also consistent with the findings of another much larger study, albeit undertaken in another industry. In a 2 year prospective cohort study of 13,873 materials handling employees in 160 retail merchandise stores to evaluate the effectiveness of using back belts in reducing back injury claims and low back pain, *Wassell et al (2000)* found that "*neither frequent back belt use nor a store policy that required back belt use was associated with reduced incidence of back injury claims or low back pain*".

All these studies into the benefits of back belts in preventing back injuries confirmed the findings of a major review conducted by NIOSH in 1994 of twenty-one studies then published in the peer reviewed scientific literature. *NIOSH (1994)*[2] found that "*the effectiveness of using back belts to lessen the risk of back injury amongst uninjured workers remains unproven*" as many of the published studies returned inconclusive findings and those few which reported positive results were methodologically flawed.

The findings of both *Smidt (1998)* and *Reddell et al (1992)* that lifting training had no effect on baggage handlers' back injuries, was also supported by a 2001 paper (*Linton and van Tulder (2001)*) which reviewed nine separate randomised trials undertaken across a range of industries, into the effect of back schools[16] on back and neck pain and found there was "*strong evidence that back schools are not effective in prevention*".

Two further studies investigated the benefits of baggage handlers lying supine during rest periods. *Leskinen et al (1991)*, in their study of changes in the body height of 19 volunteer baggage handlers during a work day, went on to suggest that resting supine, even for short periods, improved spinal disk nutrition and would be beneficial in reducing the instance of baggage handler back strain. *Stălhammar et al (1991)* also found that lying supine during rest periods increased fluid exchange into the vertebral discs which improved nutrition of the disc tissue and would aid resistance to back sprains and strains.

Since the early 1990s, many airlines have provided facilities for baggage handlers to have horizontal rest between baggage handling work periods. However, in the opinion of Cree (*Cree (2003)*), the facilities often do not get utilised effectively unless the baggage handlers are closely and consistently supervised and as a result, the use of such facilities does not lead to a noticeable reduction in injuries rates in normal airline operations.

Clearly all these study outcomes reported in the literature support the principles of the hierarchy of hazard controls. All these lower order hazard control methods, the administrative controls of lifting training and resting techniques, and back belts, supposed to be personal protective equipment, have been found to be ineffective as injury prevention methods.

[16] Back schools were defined as training that included discussions with trial subjects on anatomy, biomechanics, lifting techniques, postural issues related to the work and a program of exercises.

The Load: The Reduction of Baggage Weight

In 1993 four airlines, Qantas Airways, Ansett Australia, Air New Zealand, and Ansett New Zealand, voluntarily introduced procedures to limit baggage weight to below 32kg as a baggage handler injury prevention initiative (see Figure 1.27). 32kg had been a pre-existing notional weight limit across the worldwide industry, after which excess baggage fees would have been charged to the passenger. Posters and warning material at check-in locations elevated the profile of the weight limit, and procedures at check-in locations ensured baggage over 32Kg was re-packed prior to check-in.

However, other airlines were slow to adopt the concept.

Figure 1.27
Qantas Baggage Weight Limit Advertising
1993

At a meeting of the Ergonomics Sub-committee of the International Air Transport Executive (ARTEX) of the National Safety Council of America, in Brussels, Belgium on June 5, 1995 (*ARTEX (1995)*), the majority of airline representatives felt that many airline commercial department managers and supervisors, would turn a blind eye to the injury risk to baggage handlers exposed to heavy baggage, rather than refuse to uplift a passenger's heavy bag or put the passenger to the inconvenience of re-packing their bag to reduce the weight.

In 1999, the International Air Transport Association (IATA), the world-wide representative body of airlines, following an approach from *ARTEX*, agreed to include a warning about the weight of baggage in the *IATA Airport Handling Manual*, the document most major airlines use to plan and organise their airport operations (*Briggs (1999)*). When introduced in 2000, the warning stated:

> "*Research has determined that manual handling of baggage/material is a primary cause of personnel injuries*"

However, IATA made no recommendation on a maximum weight for baggage, rather included a recommendation that:

> " '*Heavy baggage' tags/labels should be placed on all bags/materials weighing 25kg or more*" (*IATA (2001)*).

Since 2000, more airlines and airports have introduced baggage weight limits, many adopting the same 32kg limit. In June 2004 Heathrow Airport established a 32kg per item weight limit with a requirement to put "heavy tags" on bags over 23kg *(BLLA (2004))* and Edinburgh airport has introduced the same weight limits (*TUC (2004)*). Recently Doha International Airport, Qatar announced it will introduce a 32kg baggage weight limit from June 2005 *(ATT (2005))*. Passengers departing from these airports will be required to re-pack their luggage if they present at check-in with a bag over 32kg.

By contrast, some airlines have taken action to lower the threshold at which they charge excess baggage fees to passengers, in an effort to discourage passengers from lodging heavy baggage. In 2004, one such airline, Northwest Airlines, lowered their excess baggage fee threshold from 32kg to 23kgs after which passengers must pay a surcharge of $US25.00, but if a bag weighs between 32kg and 45kg a surcharge of $US50.00 is applied (*MDAFL (2004)*).

Whether such policies will reduce the instance of heavy baggage remains to be seen, albeit most airlines and airports are yet to introduce any baggage weight limits.

Indeed, *Anderson (1995)* played down the magnitude of the baggage handler injury problem by suggesting that the costs of those injuries was "*less then 20 dollars per flight*" when averaged over the total number of flights operated annually. *Anderson* went on to suggest that the cost of designing, fabricating and certifying a new concept mechanised baggage system for narrow-body aircraft would therefore be "*prohibitively high*". He suggested that the:

> "*least cost and lowest technical risk solution would be to impose a new low (14kg) limit for each piece of baggage*".

However, it should be recognised that if a baggage weight limit was to be set by the industry and based solely on injury prevention criteria, then it is likely that the weight limit would be significantly less than the slowly emerging 32kg industry standard, less even than *Anderson's* speculative 14kg limit, if it was to provide an effective solution for baggage handlers working in the confined workspace of narrow body aircraft baggage compartments.

For example, if a limit were set based on the Revised NIOSH Lifting Equation (see *Waters, Putz-Anderson & Garg (1994)* and *NIOSH 2004)*), where the recommended weight limit is calculated with a formula based on the co-function of a number of manual handling risk factors namely; the distance of the hands from the midpoint of the ankles, height of the hands above the floor, the vertical lift distance, the symmetry of the lift from the start posture to the end posture and the frequency of the lifting task, then the maximum baggage weight limit to minimise risk of injury to baggage handlers working outside the aircraft and transferring baggage onto belt loaders from baggage trailers would be less than 6kg[17].

[17] Assuming the baggage handlers' hands were as close as possible to the body at the start of the lift, ie within 25cm of the midpoint of the ankles, the hands were positioned 100 cm from the ground at the start and finish of the lift, the baggage handler did not reach outwards at all when placing the bag on the belt loader, did not rotate more than 40 degrees at the waist between picking up the bag and placing it on the belt loader and did not lift more than 5 items per minute.

The Revised NIOSH Lifting Equation has been subject of both positive and negative criticism in the literature. Early negative criticism centred on the limited validation undertaken by NIOSH before the Equation was released for use, although there have since been validation studies, for example *Weames, Stothart and Robertson (2006)*, who compared output variations in the Revised NIOSH Lifting equation with EMG measurements of the M. Erector Spinae muscle of ten healthy male subjects The study confirmed the efficacy of the NIOSH Equation in general, but criticised the Equation for not being as sensitive to subtle variations in the various risk factors as were the EMG readings. However, the literature revealed that other authors have used the Revised NIOSH Lifting Equation to provide simple, straight forward and effective assessment of manual handling tasks. For example *Meyers et al (1998)*, utilised the Equation to determine an appropriate weight reduction in grape pickers' baskets which had a positive effect in reducing musculoskeletal injury rates in the grape pickers that participated in the study.

However, a significant limitation on the suitability of the Revised NIOSH Lifting Equation for consideration of baggage handler injury risk, is that the Equation assumes an unrestricted, standing posture in a favourable environment. It cannot be used for calculating lifting limits in restricted workplaces that require stooping or kneeling postures (*Waters, Putz-Anderson & Garg (1994))*, such as those postures adopted by baggage handlers working inside an aircraft baggage compartment.

The manual handling guidance material published by the UK Health and Safety Executive (*HSE (2004)*) recommended a weight limit of 5kg for male workers that are required to lift over shoulder height and reach out to arms length, as Figure 1.28 shows. Since baggage handlers working inside aircraft baggage compartments are routinely required to lift above shoulder height and reach to arms length to stack the baggage, this HSE recommended limit could be applied to that activity. However, it can be seen that the *HSE (2004)* model was also intended to provide direction on weight thresholds for managing the risk of musculoskeletal injuries during lifting in standing postures, and so there would be a case for the weight limit to be reduced even further, below 5kg, to accommodate the additional risk factors associated with the kneeling working postures adopted in the aircraft baggage compartments, as suggested by *Waters, Putz-Anderson & Garg (1994)* in relation to the effect of similar additional risk factors on the outcome of the Revised NIOSH Lifting Equation.

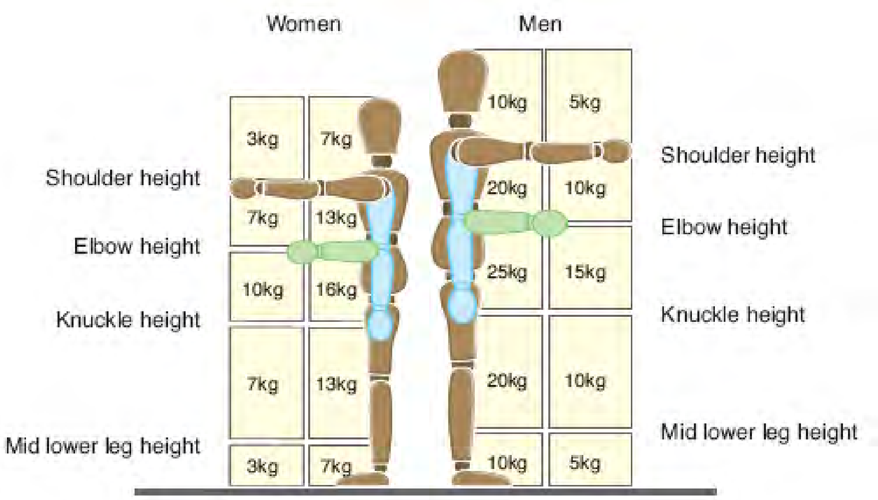
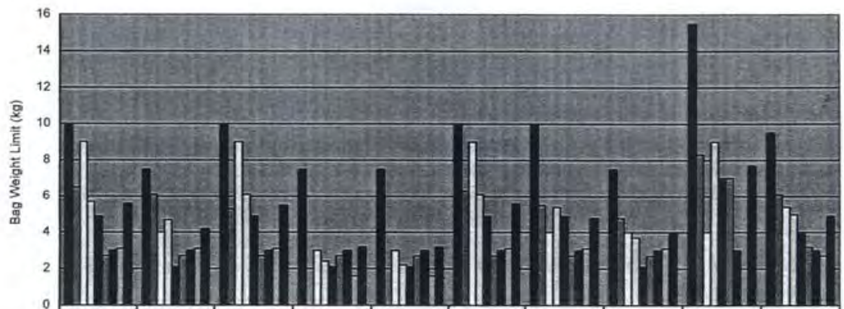


Figure 1.28
Weight Limits for "Quick and Easy" Assessment of Lifting Tasks
(from *HSE (2004)*)

As part of a review of baggage handling injuries at Qantas Airways, *Culvenor (2004)* calculated maximum baggage weight limits for nine of the routine baggage handling tasks described above using the criteria of eight different national and biomechanical manual handling standards, including the above NIOSH and UK HSE models.

Even though all of the national and biomechanical manual handling standards were based on different assumptions with different inclusion and exclusions, all standards used by *Culvenor (2004)* provided guidance on lifting thresholds above which the risk of injury should become a concern. Figure 1.29, from *Culvenor (2004)*, shows that when these standards were applied to the baggage handling tasks, the results overwhelmingly indicated baggage weights needed to be limited below 10kg for all baggage handling activities to ensure effective manual handling risk control, if baggage weight was relied upon as the only method of intervention.

There is no doubt that without regulatory intervention, the airline industry would have extreme difficulty introducing a baggage weight limit as low as 10kg, let alone the 6kg or 5kg limit that would be necessary for an effective solution for baggage handling tasks inside aircraft baggage compartments, as indicated by the NIOSH and UK HSE models.



	Racetrack/Lateral Belt to Barrow	Racetrack/Lateral Belt to Container	Barrow to Belt Loader	In hold - load	In hold - strip	Belt Loader to Barrow	Barrow to carousel belt	Container to carousel belt	Check-in and baggage	Average
Washington	10.0	7.5	10.0	7.5	7.5	10.0	10.0	7.5	15.5	9.5
NIOSH	6.5	6.1	5.3	NA	NA	6.3	5.5	4.8	8.3	6.1
Biomechics	9.0	4.0	9.0	3.0	3.0	9.0	4.0	4.0	4.0	5.4
Snook & Ciriello	5.7	4.7	6.1	2.4	2.2	6.1	5.4	3.7	9.0	5.0
HSE (UK)	4.9	2.1	4.9	2.1	2.1	4.9	4.9	2.1	7.0	3.9
Humanscale	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	7.0	3.2
Sweden	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Denmark	3.1	3.1	3.1	1.6	1.6	3.1	3.1	3.1	NA	2.7
Average	5.6	4.2	5.5	3.2	3.2	5.6	4.8	3.9	7.7	4.9

Figure 1.29
Bag weight limits for the various baggage handling tasks:
Derived from eight national manual handling standards
(*from Culvenor (2004)*)

Worldwide agreement amongst airlines would be almost impossible to achieve voluntarily given the chequered experience with the introduction of the arbitrary 32kg limit. Furthermore, there would no doubt be significant resistance from the airline passenger community faced with the practical ramifications of such a low per item baggage weight limit. Passengers would have to pack 3 or 4 smaller bags instead of the single much heavier bag now permitted. Also of course, the impact of a three or four fold increase in the number of baggage items passing through the airports, on both the baggage handlers themselves and on the rest of the airport operations, would need to be carefully assessed.

These difficulties with the application of administrative solutions clearly suggest a solution to the baggage handler injury problem lies elsewhere. The literature clearly puts the limited effectiveness of past administrative interventions of the airline industry into perspective. It is not surprising that injury rates have continued at high levels when the interventions applied in the past have focused on dubious alterations to the baggage handling tasks, training in supposed safe lifting techniques, changes to methods of rest between work periods and inconsequential reductions in the weights of baggage. Indeed, the poor injury performance outcomes achieved could have been expected based solely on the understanding of where these interventions fit into the Hierarchy of Hazard Control theory.

Accordingly, it is obvious that the focus needed to shift to design solutions that had the potential to significantly reduce the manual handling risks. As a result, key objectives of this study were the measurement of the impact of the ACE and Sliding Carpet systems on injury risk, building on the preliminary work mentioned above of *Jorgensen et al (1987)* and *Stokholm (1988)*, and also the assessment of the potential effect of new ground handling equipment solutions that have the potential to significantly alter the nature of the manual handling tasks performed by baggage handlers when stacking baggage into narrow body aircraft.

CHAPTER TWO: AIMS, OBJECTIVES & METHODS

2.1 INTRODUCTION

At the time this research project was in its genesis in early 1994, there were only nine research papers in the literature, including five from Scandinavia, that reported on studies of manual handling in the baggage handler workforce: *ARTEX (1981)* measured the instance of baggage handler back injuries in a cross-section of its member airlines in 1977; *Stălhammar et al (1986)*, studied the manual handling workload of nineteen baggage handlers in Helsinki and explored the back injury prevention benefits to the baggage handlers of resting supine; *Stokholm (1988)* canvassed opinions of baggage handlers at four Scandinavian airports concerning the perceived benefits of a trial *Sliding Carpet* installation in an SAS DC9; *Jorgensen et al (1987)*, investigated the frequency of back injuries in baggage handlers at three Scandinavian airports and measured the effect on workload of six baggage handlers using a trial installation of an *ACE* loading system in an *SAS* DC9 aircraft; *Lundgren, Soderqvist, Larsson and Jernberg (1988)* investigated the costs of injures to SAS baggage handlers at Stockholm Airport in 1988; *Leskinen et al (1991)* reported on the back injury prevention benefits to the baggage handlers of resting supine; *Queinnec and Daniellou, (1991)* investigated the instance of back injuries resulting from baggage handling work; *Egeskov (1992)*, looked at the effect of using a belt loader on the manual handling load of baggage handlers required to work in the doorway of Australian Airlines B737 aircraft baggage compartments; and *Ruckert, Rohmert and Pressel (1992)* explored the strain on baggage handlers during luggage handling at a German airport. These were reported in more detail in Chapter 1.

Several questions remained unanswered in the literature:

What were the aircraft manufacturers doing about the baggage handler injury problem, after all the aircraft and aircraft equipment designs were at the core of the issue?

What was the magnitude of the baggage handler injury problem world-wide?

Had the airlines' safety personnel looked into the issues and what were their views?

What were the opinions of the baggage handlers themselves about the causes of the injuries?

What were the comparative benefits of the ACE and Sliding Carpet narrow-body baggage systems that were being promoted in the industry as potential solutions?

Were any aircraft ground support equipment manufacturers or others offering any solutions and if so, what were the merits of those solutions?

While it could be argued that there were many more questions unanswered regarding the causes and prevention of baggage handler injuries, widespread improvements were considered to be unlikely unless these questions were clearly answered. Accordingly, this research project, in five phases, was developed to investigate answers to these questions. In addition to the overall project aims and objectives, each phase of the study had its own research aims, objectives and methods. The five project phases were conducted in sequence and as such, each phase added to the body of knowledge and informed the conduct of subsequent phases.

The phases of this research project were:

Phase 1 Meetings were held with representatives of the major aircraft manufacturers, aviation safety organisations and aviation industry bodies to ascertain the level and nature of industry activity in relation to airline baggage handler back injuries.

Phase 2 A survey of airlines worldwide was conducted to quantify the magnitude of the baggage handler injury problem and to ascertain the opinions of airline safety professionals concerning causes and prevention.

Phase 3 A survey of airline baggage handlers was conducted worldwide to ascertain their views on causes and prevention

Phase 4 Laboratory trials, analysis and testing was carried out of two commercially available baggage systems, *ACE* and *Sliding Carpet* suggested by some to be part of the solution to the baggage handler injury problem

Phase 5 A risk assessment of the *Longreach Loader*, a prototype ground handling technology designed to reduce the manual handling workload of baggage handlers loading aircraft was carried out.

To maximise the impact of the research on the worldwide aviation community, the results of each phase were to be published in the literature after completion of the phase, or where appropriate, presented at aviation industry safety symposia.

Only one other empirical study has been published since 1998 in the baggage handler injury area. *Korkmaz et al (2006)* conducted laboratory trials involving twelve healthy male university students who had been trained in baggage handling techniques used by airline baggage handlers. The trial subjects were required to perform a baggage stacking task in a laboratory mock-up that simulated the low baggage compartment ceiling of a B737 aircraft. It was of interest that *Korkmaz* and colleagues relied significantly on the papers published earlier in this study (*Dell (1997)* and *Dell (1998)*) to contextualise their work. The authors investigated the effect of two administrative interventions; the effectiveness of providing weight information on each bag to forewarn the baggage handler before lifting and the effect of stacking bags on end instead of the horizontal orientation usually adopted by baggage handlers. The measures used were spinal loading and trunk and shoulder muscle activity, determined using a Lumbar Motion Monitor, a ground force plate and surface EMG to measure muscle activity. The study found that there was no significant difference in trunk kinematics or spinal loads as a result of subjects being forewarned regarding the weights of bags being handled when loading order was random as would normally be the case during actual aircraft loading operations. However, if the weight of bags was used to inform the order in which the bags were loaded, mean spinal compression reductions of 13.5% were achieved, mean spinal anterior/posterior shear loads were reduced by 16.2% and mean spinal lateral shear loads were reduced by 17.5%.

Korkmaz and colleagues also claimed that stacking bags on end significantly reduced spinal loads. Reduction in mean peak spinal compression of 21.4% was measured, mean spinal anterior/posterior shear loads were reduced by 20.4% and mean spinal lateral shear loads were reduced by 32.4%, suggesting alteration to baggage stacking methods by airlines in this fashion could be an effective intervention. However, for this part of the analysis, *Korkmaz* and colleagues indicated that each trial subject was measured tipping only one bag on end and this was compared to loadings measured when stacking only three bags horizontally on top of one another. The possible effects of attempting to stack a full aircraft load of baggage in this fashion, where the practicality of maximising use of volumetric baggage compartment capacity, a daily problem for baggage handlers, was not considered. This places serious doubt about the real world viability of this potential solution.

Excluding the contributions made by the presentation and publication of the first three phases of this research, the research questions posed above remain largely unanswered in the literature at the time of writing this Thesis, underpinning the validity of the rationale taken in the original research design and study methodologies described here.

2.2 RESEARCH AIMS AND OBJECTIVES

Project Aims and Objectives

The aim of this research project was:

> *To investigate the level of awareness of global stakeholders on the baggage handler back injury problem, measure the magnitude of the problem in the aviation industry, identify the causes of baggage handler back injuries, identify potential solutions and measure their effectiveness, where possible*.

There were eight project objectives. These are detailed in Table 2.1.

Table 2.1
Objectives of the Project

Objective 1	Engage the major jet passenger transport aircraft manufacturers and industry associations in the issue of baggage handler back injuries
Objective 2	Investigate the level of awareness of the issue amongst international safety organisations
Objective 3	Encourage aircraft ground support equipment manufacturers to examine the issue and develop solutions technologies
Objective 4	Investigate the costs of baggage handler back injuries in the world's major airlines
Objective 5	Canvass the opinions all the airlines' safety professionals regarding the causes and prevention of baggage handler back injuries
Objective 6	Survey the opinions of a cross-section of baggage handlers worldwide regarding the causes and prevention of baggage handler back injuries
Objective 7	Explore whether safe design interventions can effectively reduce the risk of injuries occurring in one of this most severe manual handling work environment by comparing the effectiveness of the *ACE* and *Sliding Carpet* narrow body aircraft baggage systems
Objective 8	Assessing the change in manual handling risk associated with the use of the prototype *Longreach Loader* that was designed to reduce the need for baggage handlers to lift baggage and cargo when loading or unloading narrow body aircraft
Objective 9	Develop a series of recommendations to reduce the occurrence of back injuries in the airline baggage handler workforce

Summary of Key Project Activities

The key research activities undertaken in this project and those that were intended to engage the airline industry are described in Table 2.2.

Table 2.2:Key Project Activities

1994 Dell conducted internal investigation into: • Costs of baggage handler back injuries at Qantas • Opinion of Qantas OH&S Reps on issues causing injuries
1994 Dell developed white paper for presentation to industry
1994 Dell presented white paper to international aviation safety conferences at Memphis & Fiji
1995 In Phase 1 of this research, Dell presented white paper to senior design engineers of the major jet aircraft manufacturers: • Boeing in Seattle, USA • McDonnell Douglas in Long Beach, USA • British Aerospace/Avro in Woodford, UK • Airbus Industrie in Toulouse, France • Fokker in Amsterdam, Holland
1995 In Phase 1 of this research, Dell visited other airlines to film and observe baggage handlers operations using the Sliding Carpet and ACE narrow body stacking systems: • Sliding Carpet in MD83 aircraft at SAS in Stockholm, Sweden • Sliding Carpet in MD87 at SAS/Linjeflug in Copenhagen, Denmark • Sliding Carpet in A320 aircraft at United Airlines in San Francisco, USA • ACE in B727 aircraft at United Airlines in San Francisco, USA • ACE in B737 and B757 aircraft at United Airlines in Los Angeles, USA
1995 In Phase 2 of this research, conducted a survey of airlines safety managers to quantify the baggage handler injury problem and ascertain their opinions concerning causes and prevention.
1996 In phase 3 of this research, conducted a survey of airline baggage handlers to ascertain their opinions concerning causes and prevention of baggage handler back injuries.
1998 In Phase 4 of this research, conducted laboratory trials and ergonomic analysis of ACE and Sliding Carpet Narrow-body aircraft baggage systems
1995 to 2000 Dell presented papers to key industry safety conferences: • Brussels, Belgium - May 1995 • Sydney, Australia - January 1996 • Calgary, Canada - June 1996 • Mexico City, Mexico - February 1998 • Seattle, USA - June 1998 • New Orleans, USA - October 1999 • Perth, Australia – April 2000
2003 In Phase 5 of this research, conducted a risk assessment of the prototype RTT Longreach Loader to ascertain its impact on the manual handling risk to baggage handlers using the loader to load baggage into aircraft

2.3 METHODS EMPLOYED IN EACH PHASE OF THE PROJECT

Phase 1: Engaging the Aircraft Manufacturers and Industry Associations

This phase of the study comprised a series of industry presentations and meetings with aircraft manufacturers, to ascertain their state of knowledge regarding the baggage handler injury issue. Preliminary inquiries within Qantas Airways and Ansett Australia Airlines in early 1994, led to development of a discussion paper titled "*Airline Baggage Handler Back Injuries: Our Prevention Obligations*" (see Appendix No. 1) which was then used to address the industry organisations and provide a focus for discussions with aircraft manufacturers.

In the period May 1994 to September 1995, the discussion paper was presented by the writer to design engineering representatives from five aircraft manufacturers, namely Boeing and McDonnell Douglas in USA and Airbus Industries, BAe AVRO and Fokker in Europe. Also, the discussion paper was presented to the symposia of two aviation industry safety organisations, namely the Australasian Aviation Ground Safety Council (AAGSC) and the National Safety Council of America, International Air Transport Executive (ARTEX). All major airlines in Australia, New Zealand and the south pacific were members of the AAGSC and ARTEX membership comprised most of the world's major airlines.

A full listing of all presentations and journal articles published as part of this research project is at Appendix No. 2.

The presentations to the industry groups were used to foster support for this research project and to identify others who were working on the issue.

The following issues were canvassed with the each of the aircraft manufacturers:

Were they aware of the problem of manual handling injuries to airline baggage handlers?

Were they taking any action to address the problem?

Were they aware of any other organisations working on the baggage handling injury issue?

Were they willing to review their aircraft baggage compartment designs?

Would they participate in activities to help develop lasting solutions?

Phase 2: Survey of Airline Safety Professionals to Quantify the Baggage Handler Injury Problem and Ascertain their Opinions Concerning Causes and Prevention

A questionnaire was developed and circulated to the occupational health and safety professionals of thirty two airline and ground handling companies worldwide who employ baggage and cargo handling staff. Eighteen responded, however, two provided insufficient information to be included in the data set.

The sixteen companies who provided useable data were: Sabena Belgian Airlines, Thai Airways International, Swissair, Qantas Airways, Air New Zealand, Canadian Regional Airlines, DHL Aviation , Canadian Airlines International, Hong Kong Air Terminal Services, Delta Airlines -Germany , Ansett Australia, KLM, Ansett New Zealand, Eagle Airways, Delta Airlines-USA, and American Airlines.

The questionnaire was in two parts, those questions intended to quantify the costs and magnitude of the back injury problem (Part A) and those intended to investigate the causes of back injuries and any preventive measures their organisations had attempted (Part B), as follows:

PART A

In order to validate the anecdotal information on the magnitude of the baggage handler back injury problem, the industry safety professionals were asked to provide information in relation to their operation, for the years 1992, 1993 and 1994. They were each asked to provide the number of baggage handlers their airline employed per annum, the average number of hours worked per week per baggage handler, the number of lost time back injuries[18] per annum and the annual cost of those injuries[19].

Response data obtained was used to calculate annual lost time injury frequency rates (LTFRs) per million hours worked for the total baggage handler population and the average cost per injury per annum.

PART B

The questionnaire also sought information from the safety professionals on the causes and prevention of baggage handler injuries.

The safety professionals were asked whether baggage handlers in their organisations were required to lift baggage and cargo exceeding 32Kg (70lb) weight. 32Kg was a pre-existing notional industry limit on passenger baggage weight. They were also asked to select from a list of twelve manual handling tasks routinely carried out by baggage handlers, which they considered to be the five (5) most likely to cause baggage handler back injuries. The safety professionals were also asked what back injury control measures had been applied in their companies? In particular, information was sought on use of

[18] Lost Time Back Injury was defined as the failure, following the injury, to report for duty at commencement of the next work shift.
[19] Cost was defined as including workers compensation, medical and rehabilitation expenses.

back support belts, back care training, use of ground equipment, use of narrow body aircraft in-plane baggage stacking systems and details of any attempts at airport terminal re-design applied to reduce the instance of baggage handler manual handling injuries. Finally, they were asked for their opinions on what measures they believed would be necessary in future to reduce the instance of back injuries to baggage handlers. A copy of the questionnaire is at Appendix No. 3.

Phase 3: Survey of Airline Baggage Handlers Opinion on the Causes and Prevention of Baggage Handler Back Injuries

A questionnaire was developed to canvass baggage handler opinion on the causes and prevention of baggage handler back injuries. A copy of the questionnaire is at Appendix No. 4.

Questionnaires were sent to all member airlines and ground handling companies of the AAGSC and ARTEX, and the company safety managers were contacted to gain their support in conduct of the survey. Aerolineas Argentinas - Argentina, Austral Airlines - Argentina, Delta Airlines – Germany, Delta Airlines – USA, Lufthansa - Germany, Northwest Airlines – USA, Midwest Express USA, Qantas Airways– Australia, Scandinavian Airline System - Scandinavia, Service Master - USA, CLT Aviation – USA participated in the survey.

Respondents were selected at random from the baggage handler work force at each organisation. The safety managers[20] of the participant airlines supervised the survey process and ensured the fidelity of questionnaire completion.

[20] With the exception of the SAS baggage handlers, who were surveyed individually by Professor T. Larsson during a return visit to Stockholm, and the Aerolineas Argentinas and Austral Airlines baggage handlers who were surveyed individually by the writer during a visit to Buenos Aires.

The questionnaire was translated into Swedish and Spanish for the baggage handlers of SAS and the Argentine airlines, respectively.

The questionnaire sought the baggage handlers' opinion on a range of issues including; how long had they worked as a baggage handler, what was their age and gender, had they personally experienced a back injury, how often did they experience back pain and whether baggage handlers in their organisation were required to lift baggage and cargo exceeding the notional industry baggage weight limit of 32Kg (70lb). Baggage handlers were also asked to select from a list of 5 baggage handler workplaces, which they considered were most and least likely to cause back injuries and from a list of twelve manual handling tasks routinely carried out by baggage handlers, which they considered to be the five (5) most likely to cause baggage handler back injuries.

In addition, the survey sought baggage handler opinion on what back injury control measures had been applied in their companies. In particular, information was sought on use of back support belts, back care training, use of equipment, use of narrow body aircraft in-plane baggage stacking systems, such as Sliding Carpet and ACE, and details of any attempts at building re-design to reduce the instance of baggage handler manual handling injuries. Finally, baggage handlers were asked for their opinions on what measures they believed would be necessary in future to reduce the instance of back injuries to baggage handlers.

Phase 4: Laboratory Trials and Ergonomic Analysis of *ACE* and *Sliding Carpet* Narrow-Body Aircraft Baggage Systems

As mentioned in Chapter 1, when aircraft compartments fitted with either *ACE* and *Sliding Carpet* were loaded or unloaded, one baggage handling task was eliminated. The need to shift baggage from the doorway into the compartment interior during loading, the task shown in Figure 1.8, and vice versa during unloading, had been eliminated by the forward and aft movement of the *ACE* telescoping bin sections and by the belt section of the *Sliding Carpet*. This had been reported by all the authors who have looked at these systems in the past (see for example *Stokholm (1988)* and *Jorgensen et al (1987)*).

However, the manufacturers of ACE and Sliding Carpet both claim their systems' reduced injuries to baggage handlers, as reported in *Briggs (1996)*. Telair (2005) suggested Sliding Carpet "*reduces risk of operator injuries to an absolute minimum*" and ACE advertising claimed a "*75% reduction in personnel injury costs*" (see Appendix No 5).

Yet to the casual observer, there seemed to be little difference in the work for the baggage handlers who were tasked with stacking baggage into either system, and on the face of it, little difference to the work required to stack baggage in a compartment without any system fitted. For example, Figure 1.9 shows baggage being stacked into an Australian Airlines B737 baggage compartment with no system fitted, Figure 2.1 shows a baggage handler stacking cargo into a Sliding Carpet equipped Qantas B737 in Melbourne in 1999 and Figure 2.2 shows baggage being stacking into an ACE equipped United Airlines aircraft in 1995. The postures adopted by the baggage handlers in the three scenarios are very alike.

Accordingly, the research questions left unanswered were; what difference, if any, do *ACE* and *Sliding Carpet* narrow–body systems make to the risk of injury to the person tasked with stacking the baggage into narrow-body aircraft, and what are the relative benefits of the two systems, if any?

Figure 2.1
Stacking cargo in a B737 baggage compartment fitted with Sliding Carpet

Figure 2.2
Stacking B727 baggage compartment fitted with ACE

On three separate occasions, attempts were made as part of this project to run ergonomic trials of *Sliding Carpet* using actual B737 aircraft. In 1995 in Brisbane trials were attempted using a National Jet Systems B737 (see Figure 2.3) and in March 1999 in Melbourne attempts were made using a Qantas B737 (see Figure 2.4). On both those occasions, the aircraft made available by the airlines were "operational spare" aircraft that were on stand-by should an unserviceability to another aircraft in their operation occur. As such, the trial aircraft's electrical systems were energised and the airconditioning was running. Both times the aircraft systems interfered with the monitors (Melbourne: heart rate and O_2 consumption, Brisbane: heart rate) and transmitters worn by the subjects and scrambled the data. Both times the data was completely corrupted or rendered impossible to interpret.

In both attempts, the physical structure of the aircraft severely restricted camera positioning. This made the video footage inconsistent and ineffective. Also, on both these occasions, the baggage handlers provided by Qantas to participate in the trials were recalled to fill rostering gaps in the airports' normal operations before completion of the trial sequences.

The third unsuccessful trial attempt was in October 1997. Boeing had offered the use of its B737 interiors development fuselage in the factory in Seattle, Washington. A *Sliding Carpet* system had previously been installed in the development fuselage for demonstration purposes and Alaskan Airlines offered to provide baggage handlers from Seattle/Tacoma (SEA-TAC) airport. These trials were abandoned the week prior to their scheduled commencement when Alaskan Airlines expressed concern about releasing enough baggage handlers for the expected duration of the trials and it proved difficult and cost prohibitive to source appropriate cameras and video mixing equipment to use at Boeing.

As a result of these experiences, it was decided to construct a mock-up of a B737 baggage compartment in the Human Movements Laboratory at the University of Ballarat.

Figure 2.3
Attempted Ergonomics Assessment of Sliding Carpet using a mock-up fitted to a National Jet B737 aircraft in Brisbane, December 1995

Figure 2.4
Attempted Ergonomics Assessment of Sliding Carpet fitted to Qantas B737 aircraft in Melbourne, March 1999

Indeed, the conduct of trials using a mock-up had a number of significant benefits over using actual aircraft. The video capture constraints caused by the aircraft structure that were experienced in the earlier trial attempts were eliminated and trial scheduling difficulties due to the limited availability of aircraft were also resolved. Obviously, the mock-up would not be required at short notice for revenue operations. Most importantly, conduct of the trials in the laboratory at Ballarat ensured the volunteer baggage handlers were taken away from the airport and they could not be readily recalled into line operations to fill roster gaps, as had happened on both the first two attempts. In addition, the laboratory environment permitted more fidelity in experimental control and use of the mock-up eliminated restrictions on data acquisition caused by aircraft systems interference.

Above all, use of an appropriately designed mock-up allowed both Sliding Carpet and ACE systems to be accurately simulated and compared, a circumstance not possible using an actual aircraft.

Sliding Carpet and Ace B737 Mock-up:

Since there were more Boeing B737 aircraft in Australia and overseas than any other narrow-body aircraft type, it was decided to design the mock-up to simulate baggage compartment No. 3 of a B737-400 aircraft. In the past, when B737 aircraft had been fitted with *Sliding Carpet* or *ACE* systems, Compartment No. 3, the compartment immediately aft of the wing, was commonly fitted with a system.

Figure No. 2.5 shows the original design drawing of the mock-up, the dimensions of which were exactly consistent with those of the actual B737-400 aircraft. Boeing specifications were used in the design and confirmed by University of Ballarat Human Movements Laboratory technicians who visited Qantas at Melbourne Airport and measured actual aircraft. The *ACE* and *Sliding Carpet* systems' dimensions were taken from the manufacturer's specifications (see Appendices No. 6 and No. 7, respectively). Key dimensions relevant to this study, such as the height of the step presented to the baggage handlers by the floor sections of the *ACE* bins when the system was fully retracted (see Figure 2.6) and the equivalent belt section height of the *Sliding Carpet* (see Figure 2.7), were confirmed by correspondence with the systems' manufacturers. The manufacturers advised that these were 9cm (*ACE*) and 1.9cm (*Sliding Carpet*). The height of the belt section of *Sliding Carpet* was confirmed by direct measurement of a unit installed in a Qantas

B737-400 aircraft. No aircraft fitted with *ACE* was available for confirmation measurement.

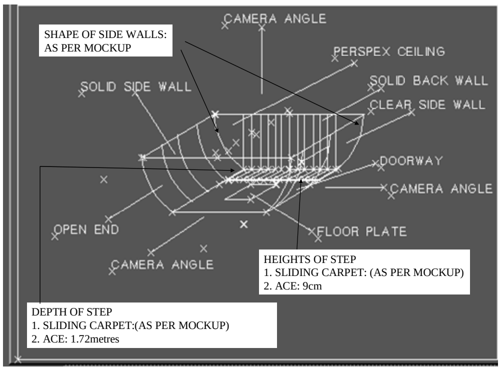


Figure 2.5
B737-400 Baggage Compartment Mock-up drawing

Figure 2.6
An *ACE* system positioned at the doorway ready for loading.
A 9cm step up from the aircraft floor

Figure 2.8 shows the completed mock-up, in *ACE* configuration, in position on the floor of the Human Movements Laboratory at the University of Ballarat.

Figure 2.7[21]
Sliding Carpet showing1.9cm step up from the aircraft floor (near end). Note: wall is moved to near end for loading

Figure 2.8
Mock-up on the floor of the Laboratory in *ACE* configuration with door and floor insert in place[22]

The mock-up design functionality simulated the restrictive working environment of the B737 aircraft baggage compartment with the same dimensions as the actual aircraft compartment. The dimensions of the B737 baggage compartment were recreated in three configurations; with an *ACE*

[21] Photo courtesy of *Scandinavian Belly Loading (1995)*
[22] Note: Clear perspex door skin, ceiling and fuselage wall section at right for overhead & lateral camera views

system installed, with a *Sliding Carpet* system installed and without either system installed.

The mock-up reproduced the typical position of the moveable walls of *Sliding Carpet* and *ACE*, in relation to the aircraft doorway, when baggage loading was taking place.

In the first position, simulating *Sliding Carpet,* the wall was positioned 1.0 metre from the nearest edge of the aircraft doorway, 900mm from the end of the *Sliding Carpet* nearest to the worker[23].

In the second position, simulating *ACE,* the wall was positioned 1.8 metres from the nearest edge of the aircraft doorway, 1.7 metres from the end of the *ACE* system nearest to the worker.

Inserts were added on the floor of the mock-up to simulate the different floor section heights of *ACE* and *Sliding Carpet*. These were removed to allow stacking directly on the laboratory floor to simulate the aircraft configuration when neither system was fitted to the aircraft, the mock-up configuration referred to as “No System” in this study. Also, in the “No System” configuration, the mock-up design allowed the aircraft door to be removed, since the bag stacking tasks in “No System” aircraft configuration occurred in the interior of the compartment, several metres away from the doorway, so the aircraft door was not present in the baggage handlers working environment while doing the task.

Table 2.3 summarises the mock-up configurations used to simulate the *ACE*, *Sliding Carpet* and “*No System* working environments.

Table 2.3
Configuration of the mock-up for the three systems
ACE*, *Sliding Carpet* and "*No System

System Simulation	Wall Position	Floor Insert	Door Installed
ACE	Position 2	9.0cm insert	Yes
Sliding Carpet	Position 1	1.9cm insert	Yes
No System	Position 1	Nil	No

The mock-up ceiling and door skin were made from clear perspex to permit the overhead camera to have a clear view of baggage handlers working in the mock-up while still providing a height restriction on the baggage handler's equivalent to that of the actual aircraft compartment ceiling. The section of fuselage side-wall adjacent to the doorway was also made from clear perspex to permit the lateral camera to have a clear view of baggage handlers working in the mock-up, especially when simulating the ACE system configuration where the moveable wall was almost two metres from the door frame.

Figure 2.9 is a view of the mock-up in position in the laboratory showing the perspex section of fuselage wall to the right of the doorway opening. Figure 2.10 shows the position of two of the cameras, the overhead camera and the aircraft centre line camera. Figure 2.11 shows the third (lateral) camera position and a view of the baggage used in the trials.

[23] Measurements of United Airlines and Qantas aircraft showed the ends of the *ACE* and *Sliding Carpet* systems nearest the aircraft doorway were both approximately 10cm from the nearest edge of the doorway.

Figure 2.9
Mock-up in position showing perspex fuselage section to right of door opening.

Figure 2.10
The mock-up in position in the laboratory showing the overhead and centreline camera positions.

Figure 2.11
View of laboratory showing position of third (lateral) camera (arrow) and trial baggage. Note: Mock-up is off picture to the left

Experimental Design

A key feature of the experimental design for this phase of the research was that each baggage handler was being compared only with themselves. The basic premise was to control all other variables so that between each trial sequence, only the mock-up configuration changed, and then any differences observed in the postures adopted by the baggage handlers could be attributed to their reaction to the changed configuration.

Accordingly, any differences exhibited by each subject between loading baggage in the three aircraft configurations was observed and recorded. Such differences could then be construed as measures of the relative benefits or shortcomings of the *ACE* and *Sliding Carpet* systems, or indeed the relative benefits or shortcomings of not having either system (the “No System” configuration).

Another major advantage of this approach was that each subject was their own control for the whole range of potentially confounding variables related to the person, such as age, years of experience, level of training, lifting technique, height, reach capability, fitness, level of fatigue, wellness, gender etc. To ensure this circumstance was maintained, no comparisons across the trial population, between the baggage handlers, were made.

Baggage Handler Subject Recruitment

To make certain these trials had the highest possible level of credibility in the aviation industry, it was decided to persevere with using people that had airline baggage handling experience as trial subjects. Accordingly, the assistance of Qantas was sought and they arranged for personnel with baggage handling experience to participate at Ballarat University on the day of the trials.

Advice of statistics expert, Dr Jack Harvey, was sought during the trial design stage concerning the likely number of subjects needed. It was deemed almost impossible to determine in advance how many subjects would be needed, since sample sizes necessary to gain significance would be dependant on consistency of outcome measures. Not withstanding, a target number of twenty volunteer baggage handlers was considered likely to be adequate and this was passed on to Qantas in the request for support. However, as on previous occasions, due to operational demands Qantas were able to provide only nine volunteers from their baggage handling workforce on the day of the trials.

Appendix No 8 provides details of the nine Qantas personnel who participated as trial subjects. All were male between thirty-three and fifty-three years of age and had between one and thirty-one years experience handling airline baggage and cargo. The baggage handlers came from Melbourne (2), Sydney (5) and Brisbane (2) airports.

Fortunately, the subsequent significance tests showed that nine baggage handler subjects proved to be sufficient number to gain statistical significance in the trial outcomes.

Trial Methodology

The method adopted for these trials required each subject to stack baggage into the mock-up three times, once for each mock-up configuration: "*ACE"*, "*Sliding Carpet"* and "*No System"*.

In each sequence, baggage was placed near the subject working in the mock-up, one at a time in an equivalent position in relation to the baggage handler to that which would have been experienced when loading actual aircraft. This had been confirmed by prior observation of aircraft loading at Qantas Melbourne, United Airlines San Francisco and Scandinavian Airlines Stockholm.

The subject was then required to take each item of baggage and stack it against the wall of the baggage compartment mock-up.

The rate of bags being presented to the baggage handlers was controlled at a target rate of one bag every six seconds, to minimise possible resultant variation in work rate. However, sometimes baggage handlers had difficulty placing bags into the stack and this delayed the period between bags beyond

6 seconds. It also lengthened the time taken to stack the bags to the ceiling to complete the sequence.

Each loading sequence was completed when baggage had been stacked to the ceiling, as shown at right in Figure 2.12.

During each baggage loading sequence, the baggage handler working postures were video-taped using three cameras positioned 90^{o} to one another that were simultaneously mixed onto one video tape and a time sequence was automatically added. The subjects' heart rate and oxygen consumption were also monitored and recorded.

In addition to the potential confounding variables related to the subjects themselves described above, several other potential confounders were controlled by the trial methodology.

The possible variation in the size and shape of the baggage was controlled by selecting all medium sized suitcases with dimensions as consistent as possible and to control for uneven distribution of weight within each item of baggage, each bag was weighted with rags, old clothing and crumpled up newspaper to evenly distribute the weight. Differences in the weight of bags was controlled by filling each bag until it weighed 15kg gross weight[24] and possible variations in the number of bags used by subjects to fill the mock-up to the ceiling was controlled by briefing the subjects to use the same techniques and limits they would normally adopt when loading aircraft and to fill the entire space, floor to ceiling, with baggage.

To control for any pattern effects the sequence the items of baggage were offered to subjects was randomised and the order of in which the aircraft configurations, "*ACE*", "*Sliding Carpet*" and "*No System*", were presented to the subjects was randomised. The random number generator in Microsoft Excel was used to derive bag and system order.

[24] 15kg was selected to provide a load that was most unlikely to injure the trial subjects who were experienced baggage handlers, yet not be so light as to alter the work methods and postures adopted by the subjects.

A summary of the potential confounding variables identified and the methods applied to control them has been detailed in Appendix No 9.

Analysis of the 3D Video of Working Postures Adopted by Baggage Handlers

It was expected the trials would produce over four hours of video footage that recorded all baggage stacking sequences. Also, it was anticipated that the trials would potentially produce an upper limit of around 810 stacking postures, since each subject would use around thirty bags in each trial sequence to fill up the mock-up to the ceiling (nine subjects by three configurations by thirty bags). Accordingly, it was expected that there would be a need to synthesise the video data to deliver output data of useable proportions.

It was planned to analyse baggage handler postures in three worst case bag positions for each mock-up configuration. They were, stacking a bag into the top row left hand corner of the mock-up, into the top row centre of the mock-up, and into the top row right hand corner of the mock-up.

This ensured that consistent images could be provided for comparison purposes across all the trial sequences with a realistic expectation that analyses would be possible with a high level of fidelity.

Comparison of those “three top row” bag positions also maximised any influence of three of the high risk manual handling factors (see Section 1 & Table 1.1 from *Alberta (2000)*) that are evident in baggage handling activities within narrow body aircraft baggage compartments, namely lifting above shoulder height, trunk rotation while lifting and reaching while lifting.

These factors were usually in evidence during baggage stacking activities in actual narrow-body aircraft baggage compartments and had been observed during prior observation of aircraft loading at Qantas Melbourne, United Airlines San Francisco and Scandinavian Airlines Stockholm.

The “three top row” video analysis methodology provided for effective video analysis of eighty-one postural data points (nine baggage handlers by three bag positions by three baggage compartment configurations).

Of course, the raw video footage required significant editing to present the footage in a way that made it possible to compare the baggage handlers’ postures between each of the mock-up configurations.

The raw footage was edited using a professional video edit suite[25] to produce MPEG video files for subsequent analysis. Using the time sequences to align the footage, equivalent activities of each baggage handler for each of the three bag positions in each of the three mock-up configurations, were aligned for comparison.

To eliminate the potential confounding variable of order when the files were later viewed by ergonomists, it had been intended to change the order of the 3D views between each MPEG. However, this was not possible since the additional edit suite time required for this to be done would have tripled the cost of production well beyond the budget available for production of the MPEG files.

Three methods of analysis were applied to the 3D video MPEG data:

Method 1- Biomechanical modelling to provide measures of variation in disk loading of the lower back between postures exhibited by baggage handlers.

Method 2- Projection of the postural images onto a screen and directly measuring reach distances and trunk rotations to identify differences between the postures

Method 3- Surveying the opinion of ergonomic specialists regarding the differences in the risk of back injury between the postures

[25] Editing services were provided by Mr John Cadd of General Direction Pty Ltd as a commercial service and followed the instructions of the author regarding sequences and presentation layouts required.

exhibited by each baggage handler when stacking bags in each of the three top row bag positions in each of the three mock-up configurations.

Video Analysis Method 1 – Biomechanical Modelling

In order to evaluate variations in the baggage stacking postures adopted by the subjects between the three mock-up configurations, the University of Michigan 3D Static Strength Prediction Program (Michigan 3D Program) was used. The Michigan Program had been reported as an effective method of estimating variations in spinal disk compression forces and strength due to postural changes during lifting tasks (see for example *NIOSH (1997)*[2] and *Chaffin (2003)*) and has been used to enhance the fidelity of other human biomechanical modelling programs (see *Chaffin (2002)*). *Chaffin (1997)* asserted that the Michigan Program was… "*shown to be valid*" for evaluating exertions… "*such as when lifting, pushing, or pulling on heavy objects*", as is the case with airline baggage handling. Also, the Michigan 3D Program had previously been successfully applied in many other postural and musculoskeletal risk comparison studies (see for example *Marklin and Wilzbacher (1999*), *Harvey et al (2002), Silvia et al (2002) and DPW (2004)*.

Two other biomechanical modelling systems were also considered for use in this phase of the study and were both rejected. These were the Lumbar Motion Monitor and Watbak 3D. Trials with the Lumbar Motion Monitor showed that the base of the Monitor's electronic spine struck the ground frequently when worn in the kneeling postures adopted during baggage loading tasks. This caused spurious readings of spinal loading and also influenced changes in subject behaviours and postures which would have confounded the trial results.

Also, correspondence took place with the University of Waterloo authors of Watbak 3D, regarding the possible use of the program to analyse the simultaneous three camera footage from the laboratory trials in this study. However, the authors indicated in writing that Watbak 3D had been developed by extrapolating the original Watbak 2D kinesiology data and that the program was not yet proven for accurate 3D data input. Accordingly, it was decided to limit biomechanical modelling analysis to use of the Michigan 3D Program.

As described in the Back Injury Fisk Factors Section of Chapter 1, there was clear consensus in the literature concerning the significance of spinal loading in the aetiology of low back injuries *(Lindh (1980) Marras et al (1995)*, *Marras et al (1999), Marras (2000) McGill (2002*), *UOM (2004)* and *McPhee (2004)*).

Therefore, the L4L5 and L5S1 lumbar disc compression measures from the Michigan 3D Program output data were chosen for differential comparison of postures adopted by the trial subjects

The postures modelled with the Michigan 3D Program were achieved by running the MPEG videos in Pinnacle Studio software[26] and freeze frame images were taken when the baggage handlers' postures were at maximum extension in each bag stacking action. Appendix No. 10 contains figures of all eighty-one of these freeze frame images.

In each image, each row showed the posture adopted by the subject in the three simultaneous camera views. In each image, the three rows showed the stacking of a bag into the same bag position (ie top left, top centre or top right). The only difference between the three rows of images, from a methodological design perspective, was that each row depicted stacking into a different mock-up configuration, namely *ACE, Sliding Carpet* and *No System*.

The postures exhibited in each row of the freeze frames were then modelled in the Michigan Program by use of a computer with twin 50cm high definition monitors (see Figure 2.12) so that accurate modelling could be achieved. Since 32kg was the notional upper weight limit of baggage handled by Australian airline baggage handlers, this weight was used in the configuration of the Michigan Program when modelling each posture. Equal weight distribution between the hands was assumed.

[26] Pinnacle Studio Version 9 is commercially available from Pinnacle Systems Inc, Mountain View, California

Appendix No. 11 shows images of all the postures modelled in the Michigan Program.

Figure 2.12
Modelling computer with twin 50cm high definition monitors

Video Analysis Method 2 – Direct Measurement of Baggage Stacking Postures

The literature reviewed in Chapter 1 also showed that for many years it has been recognised another of the significant factors in stress on the lower back and hence the risk of injury, was the moment of the load being lifted *(Lindh (1980) Marras et al (1995)*, *Marras et al (1999), Marras (2000) McGill (2002*), *UOM (2004)* and *McPhee (2004)*). Also, NIOSH included horizontal distance as a risk multiplier in the recommended weight limit calculation associated with their Revised Lifting Equation (*CCOHS (2005)* and *NIOSH (2004))* and *Gaber (1996)* clearly related this factor as one of significance in a review of baggage handler injury causation at Frankfurt Airport.

Trunk rotation, especially rotation near the extreme range of movement, was also identified in the literature as a major factor in low back disorder occurrence (*McGill (2002) and Hedge (2006)*.

Accordingly, these factors were considered to be of significant value in the comparison of postures adopted by baggage handlers stacking baggage into the three mock-up configurations *ACE, Sliding Carpet and No System*. Clearly, if the subjects reached or twisted at the trunk consistently and significantly further when stacking in any of the mock-up configurations, then that could be construed as a predictor of differences in the risk of injury between the three mock-up configurations.

Modelling using the Michigan 3D Program had shown that when postures of extreme reach, as exhibited by some baggage handlers, were modelled, the model extended off the available screen making exact simulation of the worst reaching postures problematic (see for example Appendix No. 11 Figures A11.26 to A11.28 and A11.79). Although the Michigan 3D Program had a zoom function which permitted the image to be framed completely, it was not used. Doing so would have changed the comparative size of the subjects in each frame and had the potential of introducing a confounder to the data due to possible skewed perspective when modelling the different postures.

Therefore, the methodology developed for measuring comparative reach distances in this phase of the study, was to manually measure the reach distances exhibited directly off projected still frame images of each subjects' posture frozen at the moment of maximum postural extension.

For each subject, measurements were taken at the point of maximum postural extension for each of the "three top row" bag positions and for each compartment configuration *ACE, Sliding Carpet and No System.*

In a method similar to that of the NIOSH Lifting Equation where reach distances for standing postures were considered from the mid-point of the ankles to the hands (see *CCOHS (2005)*), it was decided for this study to measure reach from the mid point between the hips to the hand furthest from the body, since the baggage handlers in this study were lifting and reaching while in kneeling postures.

Reach distances were measured on the screen in millimetres and a conversion factor for scale based on the known dimensions of the mock-up was applied to determine the actual reach of the subjects in centimetres.

Trunk rotation angles were manually measured in a similar fashion. The postures were freeze-framed at the point of maximum differential rotation between the line of the hips and that of the shoulders and the angle was directly measured. In the same fashion as was applied for reach, measurements were taken of each subject, for each of the “three top row” bag positions and for each compartment configuration *ACE, Sliding Carpet and No System.*

Trunk rotation was measured in degrees using a simple protractor.

To achieve these measures, the MPEG videos of the subjects loading baggage into the mock-up were projected onto a flat screen using an NEC VT45 projector at a distance of 2.9 metres from the lens to the screen.

Video Analysis Method 3 - Surveying the Opinion of Ergonomic Specialists

To increase the level of confidence concerning the comparison of postures adopted by the subject baggage handlers when stacking baggage in the three mock-up configurations, a survey of the opinions of ergonomics specialists was conducted. Expert opinion surveys have been widely used for many years as an effective method of empirical research (see for example *Bray, York and DeLany (1992)* and *Rorke (2002)*). Recently *David, Woods and Buckle (200*5) successfully used an opinion survey of ergonomics and safety experts as part of the development and evaluation of an enhanced assessment tool for work related musculoskeletal disorders.

The Certified Practicing Ergonomists (CPEs) of the Human Factors and Ergonomics Society of Australasia (HF&ESA) are recognised as the peak professional group in Australia with specialist expertise in the area of biomechanics. Perusal of the CPE skills information contained on the HF&ESA website, http://www.ergonomics.org.au/ maincontergo.htm, indicated that thirty-six of the sixty-eight CPEs claimed expertise in areas relevant to this study[27]. Accordingly, the support of the HF&ESA was sought and obtained (See Appendix No. 12) for this phase of the study which involved surveying the opinions of the CPEs regarding the postures adopted by the subject baggage handlers.

All sixty-eight CPEs were sent a CD containing the twenty-seven MPEG video files, a copy of the letter of support from the HF&ESA President, a letter of introduction seeking CPE support and containing back ground information about the research as well as details of the assessment task being asked of the CPEs (Appendix No. 13) and a copy of the plain language statement from the University of Ballarat Ethics Committee approval from this phase of the project (Appendix No. 14). They were also sent a copy of the Survey Response Form (Appendix No. 15) and a "read me" file of instructions on how to manipulate the MPEG files (Appendix No. 16).

To eliminate the potential confounding variable of order of the MPEG files on the CD, the MPEGs files were randomly renumbered on each CD using the random number generator in Microsoft Excel 2003 to determine the revised file names (numbers) and hence randomise their order on each CD. A record of the file name changes was maintained for each individual CD and each response sheet was discretely numbered to match the individual CD. This permitted each subject’s responses to be reconciled with the master set of MPEG files so that meaningful analyses could be made across the data set.

The CPEs were asked to view the 27 MPEG video files and use their judgement to determine in each MPEG, which of the three postures exhibited was the one with the highest risk of a back injury, and which of the three exhibited the least risk of a back injury.

[27] The CPE skills sets were scrutinized for reference to back injuries, musculoskeletal disorders, manual handling and biomechanics.

Functionality of the MPEG video files allowed the CPEs to run the baggage stacking sequences in real time, or freeze frame at any point from the commencement of each stacking sequence, that is from when the subjects' grasped a bag until the point where they exhibited maximum postural extension at completion of the stacking task.

CPE responses were submitted on the Survey Response Form.

Twenty CPEs completed the survey.

Statistical Methods Applied in Phase 4 of the Study

Microsoft Excel 2003 was used for the tabulation and manipulation of empirical data in Phase 4 of this study. The statistics packages SPSS Version 12 and XLStat Version 7.5.2 were both used to conduct the relevant statistical tests.

This Phase of the study produced two separate data sets.

The first data set, hereafter referred to as the biomechanical data set, included the measures that were based on the Michigan 3D Program modelling and the direct measurement techniques described above. They were the load on the L4L5 vertebrale disc derived by the biomechanical modelling, the load on the L5S1 vertebrale disc derived by the biomechanical modelling, the distances the subjects' reached when stacking baggage derived by direct measurement and the angle of trunk rotation when stacking baggage derived by direct measurement.

The second data set, hereafter referred to as the ergonomists opinion data set, contained the measures derived from the survey of ergonomists opinions. The ergonomists opinions of "highest risk" and "least risk" of injury for the postures adopted by the baggage handlers in the eighty one MPEG videos were converted into ratings. A posture scored three points for each time it was judged highest risk of injury and one point for each time it was judged lowest risk, and therefore two points for the each time it was judged neither highest nor lowest. Then, for each baggage handler the scores for *ACE*, *Sliding Carpet* and “No System” for each of the three bag positions, “left”, “centre” and “right”, were aggregated.

Therefore, the worse the postures were deemed to be, the higher the rating, and the higher the aggregate rating for the respective system *ACE*, *Sliding Carpet* or “No System”.

Due to differences in the base characteristics of these two data sets, such as different subject numbers, sample and population sizes, data distributions and the number of dependent and independent variables, the two data sets were treated separately for statistical analysis.

Statistical analyses were applied to the data to ascertain whether differences measured in the postures adopted by baggage handlers for the respective systems *ACE*, *Sliding Carpet* or “No System”, and for bag positions Left, Centre and Right, were statistically significant at the 95% confidence level.

The 95% confidence level was chosen since it was generally accepted in the statistical literature as the appropriate level for rejecting the experimental null hypothesis.

To achieve this in the biomechanical data set, single tailed univariate analysis of variance (ANOVA) tests were used since it was predicted from observation of operations that *ACE* results were likely to be different to the others due to its higher floor level step and the additional distance baggage handlers had to reach because the *ACE* wall was further from the baggage handers’ in their usual kneeling position when stacking.

ANOVA was chosen as the appropriate test to ensure that not only differences between the variables were tested but that also that any between-factor effects were considered across all the data streams, that is across all the data groups for the respective systems *ACE*, *Sliding Carpet* or “No System”, for the bag positions Left, Centre Right and for all the dependant variables, namely L4L5 disc compression, L5S1 disc compression, reach and trunk rotation.

The AVOVA tests returned multiple comparisons. Post Hoc comparisons were also carried out to account for any pair wise factors and Bonferroni corrections were applied in each test to minimise the possibility of rejecting the null hypotheses by chance, since even at the 95% confidence level, one in twenty outcomes may indicate a significant difference by chance and lead to a spurious rejection of the null hypothesis when there were actually no significant variances between data groupings present (see *Caldwell, Ruxton and Colegrave (2006)*).

Mixed model analysis tests were also conducted on the biomechanical data set using SPSS to account for any random effects also taking into account both within and between subject effects that may have been present.

For the ergonomists opinion data set, two tailed multivariate analysis of variance (MANOVA) tests were applied to the data since it was not possible to predict prior to the analysis, what consensus opinions the ergonomists may have had regarding the differences in postures adopted by baggage handlers stacking baggage into the three mock-up configurations *ACE*, *Sliding Carpet* or “No System” and for the bag positions Left, Centre and Right.

The MANOVA test returned estimated marginal means and pairwise comparisons. Bonferroni corrections were also applied in each of these tests.

Statistical Corroboration

Some statistics authors warned against ignoring the intrinsic errors and assumptions of the various statistical tests. For example, there were many references in the literature that warned against erroneously rejecting the null hypothesis due to a failure to ensure the tests chosen, their underpinning assumptions and the data being analysed were fully compatible (see *Sokal (2004)* and *Caldwell, Ruxton and Colegrave (2006)*). Indeed, conduct of the Bonferroni correction with the ANOVA and MANOVA tests increased the reliability of the tests markedly when multiple comparisons of the same data sets have been conducted, as was the case in this study.

However, as *Sokel (2004)* indicated, the probability of a result that led to a spurious rejection of the null hypothesis and therefore a false claim of significance, reduced from one in twenty using an uncorrected ANOVA to about one in 200 after the Bonferroni correction, especially in simple data sets with around six variables such as those obtained in this study. It can be seen that this level of reliability, one in 200 which can be expressed as a failure probability of $5x10^{-3}$, remained far below the level of reliable engineering systems, such as the level applied elsewhere in airline aircraft operations where $1x10^{-9}$ is the target design failure probability, as described in *Dell (1999)*.

Furthermore, StatSoft (2004) warned that:

"if the result of a study was important (eg does a very expensive or painful drug therapy help people get better?), then it is always advisable to run different non-parametric tests; should discrepancies in the results occur contingent upon which test is used, one should try to understand why some tests give different results".

The consequences of a flawed or spurious outcome of the trials in this study could have a significant and lasting negative effect on the risk of injury to baggage handlers in future, the viability of the manufacturers and airline companies involved and could result in major financial losses to the industry if those defective study outcomes resulted in ineffective or harmful corrective actions.

Accordingly, in addition to the multivariate tests, the ANOVA, MANOVA and mixed model analysis outlined above, which were clearly indicated by the statistics literature to be most appropriate for analysis of the types of data involved in this study, the additional parametric and non-parametric tests described in Table 2.4 were conducted separately within the biomechanical data set and the ergonomists opinion data set, to corroborate the multivariate test results and increase confidence in the study results, particularly where any significant dissimilarity between the results for the respective systems *ACE*, *Sliding Carpet* or "No System" were indicated.

Table 2.4 Statistical Tests				
Category	**Distribution Type**	**Test Type**	**No. of Samples**	**Relationship**
Distribution Normality Tests		Shapiro-Wilk Test:		
		Jarque-Bera Test:		
		Anderson-Darling Test:		
		Lilliefors Test:		
Tests for Variance/Difference				
Parametric	Normal	Students t-test	2	Independent
		Z test	2	Independent
		Bartletts	2+	independent
		Levene	2+	Independent
Non parametric	Non-normal	Mann-Whitney	2	Independent
		Kolmogorov-Smirnov test	2	Independent
		Kruskal Wallis	2+	Independent
		Wilcoxon signed rank	2	Paired
		Sign Test	2	Paired
		Freidman,s	2+	Paired
		Multiple Comparisons	2+	Paired

For these validation tests, in order to determine which tests were the most appropriate fit for the biomechanical data set and for the ergonomists opinion data set, it was first necessary to carry out tests of each data set to determine whether the data conformed or not to a normal distribution.

When all four parametric tests described in Table 2.4 returned a normal result, the appropriate parametric tests of variance and appropriate parametric tests of difference between the data variables were applied within the data sets. When any of the four tests returned a non-normal result, the non-parametric tests of variance and the non-parametric tests of difference were applied. Appendix 17 describes in more detail the normality tests, the tests for variance and the tests for difference used for statistical validation in this study.

Where any of the tests required manual input of “one” or “two” tailed tests, two tailed tests were selected since the direction of any difference between data sets was not assumed in advance of the tests. This reduced the probability of a test returning a significant result, but increased the strength of the validation when a significant result was returned.

In all tests in this study, differences in the results between the data sets were deemed to be statistically significant when the tests were passed at the 0.05 (95%) confidence level.

Measurement of O_2 Consumption and Heart Rate:

Both O_2 consumption and heart rate have long been recognised as measures of workload. For example, *Whipp and Wasserman (1972)* confirmed the direct relationship between oxygen uptake and various intensities of workload (see also *de Cort et al (1991), AUC (2006)* and *SDSU (2006)*) and *Roscoe (1982)* confirmed that heart rate increased directly with workload in a study of over 3000 flight trials measuring pilot workload (see also *Bonner and Wilson (2002), Garet et al (2005) and Strauss (2006)*. There are also many authors who have linked increased workload with increased risk of musculoskeletal injury. For example *Krause et al (1998)*, in a five year prospective cohort study of 1449 transit operators, found that physical workload and psychosocial job factors both independently predicted spinal injury in transit vehicle operators (see also *Krauss et al (2004)* and *Cohen et al (2004)*).

Therefore, in attempt to ascertain variations in workload and therefore differences in injury risk when loading the aircraft configurations, "*ACE"*, "*Sliding Carpet"* and "*No System"* in this study, the baggage handlers' working heart rates (see *Grandjean (1988)*) and oxygen consumption were monitored and recorded during each trial sequence using a COSMED K4 Portable Metabolic Testing Unit [see Figure 2.13].

However, so that the demand of the baggage stacking work could be assessed, the "workheart rate" method described in *Grandjean (1988)* was attempted. That is, each subject had their resting heart rate recorded while they were seated. The subjects' "workheart rate", the measure of the demand of the work, was then able to be calculated by simply subtracting their lowest resting heart rate from the measures of average working heart rate recorded by the COSMED unit during each trial sequence.

Figure 2.13
Subject wearing the COSMED unit in position in the mock-up

Between each of the three trial sequences each subject rested in a seated position to permit recovery to their resting heart rate. During this time, the mock-up was reconfigured by research assistants and the baggage removed from the mock-up in preparation for the next trial sequence.

The trial design did not attempt to average heart rate over a normal work-rest regime that could be expected when loading aircraft throughout a workshift. Experience with attempted trials using real aircraft showed that h airlines were unlikely to make baggage handlers available for long enough time for such shift length measures to be taken. Also, it was considered likely that the increased workload such trials would have caused the trial subjects would have increased the risk of injury to the subjects and would have breached the University Ethics rules.

However, immediately the trials began, it became apparent that due to the relatively short duration of the loading sequences, each lasting only between 3 and 4 minutes, depending on the subjects stacking methods and techniques, the subjects' heart rates and oxygen consumptions were not reaching plateau and it would not be possible to measure heart rate and oxygen consumption differentials between the mock-up configurations: "*ACE*", "*Sliding Carpet*" and "*No System*". Accordingly, it was then realised that heart rate and oxygen consumption were not going to be appropriate with the chosen experimental design. Further comment on this issue is included in the Chapter 4 Discussion.

Phase 5: Risk Assessment of the Prototype RTT Longreach Loader

The final phase of this study was an end-user OH&S design risk assessment of the impact of the prototype *RTT Longreach Loader (RTT)* on the manual handling load of baggage handlers stacking baggage in narrow-body aircraft. The makers of *Sliding Carpet*, Telair International AB of Lund, Sweden had developed the *RTT* to compliment the *Sliding Carpet* and specifically to address the manual handling workload of the workers stacking baggage in Sliding Carpet equipped narrow-body aircraft.

RTT was designed as an attachment to the standard airline mobile belt loader which in effect extended the belt into the baggage compartment and gave the baggage handler the capability to move the end of the belt near to the position and height the baggage has to be stacked, in theory minimising the need to lift baggage within the compartment.

Figure 2.14 shows the prototype installed in position on the end of a belt loader. Figure 2.15 is a drawing of the unit on a belt loader in position at an aircraft baggage compartment door.

Telair agreed to bring the sole prototype to Australia for trials which were sponsored by Qantas Airways who were a potential major customer for RTT and had a keen interest in the machine, since all Qantas B737 aircraft had been fitted with *Sliding Carpet* since 1999.

Figure 2.14[28]
The RTT Longreach Loader

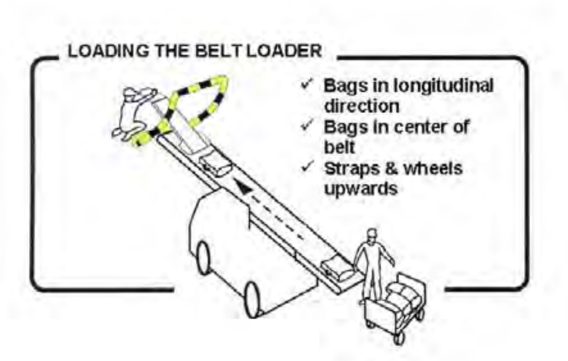


Figure 2.15[29]
RTT in position at an aircraft baggage compartment door

The risk assessment model used for this analysis of *RTT* was a derivative of that specified in Australian Standard AS/NZS 4360:1999 Risk Management and applied the following logic sequence to the *RTT* manual handling hazard analysis:

The hazards and related issues regarding the manual handling load on workers using the *RTT* to load baggage into a narrow-body aircraft were first identified and any pre-existing hazard controls evident in the prototype design or in the manufacturers draft work procedures (see Appendix No. 18) were noted. Analysis of the relative strengths and weaknesses of those hazard controls was then carried out, so that an effective estimation of the level of risk associated with the hazards could then be determined giving consideration to the effectiveness of the pre-existing hazard controls.

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[28] Photo courtesy of Telair International AB
[29] Photo courtesy of Telair International AB

Thereafter, any additional intervention strategies to mitigate the hazards or reduce the risks were identified, a prospective analysis of the strengths and weaknesses of those potential mitigations was undertaken and finally an estimate was made of the likely level of residual risk if those additional mitigations were to be implemented.

A risk assessment workshop using this methodology was conducted at Qantas Airways, Sydney Airport on May 7, 2003. The risk assessment team comprised four occupational health and safety representatives from the baggage handler workforce at Sydney Airport made available by Qantas, three design team representatives from Telair, the Qantas Manager Corporate Airports, Safety, Environment and Compliance and the author as workshop facilitator.

Before the workshop commenced, all team members were given training in the use of the *RTT* by Telair personnel and were given a copy of the draft Telair operations procedures. Also before the workshop, all team members used the prototype *RTT* to stack baggage into at least one Qantas B737 aircraft baggage compartment during Qantas normal operations.

Before assessing the impact of the *RTT*, the risk assessment team established a benchmark by assessing the stacking of baggage into a B737 narrow-body aircraft baggage compartment without the use of RTT.

Appendix No. 19 shows the assessment pro-forma used for recording decisions taken in the risk assessment workshop.

CHAPTER 3 FINDINGS

3.1 PHASE 1: ENGAGING THE AIRCRAFT MANUFACTURERS AND INDUSTRY ASSOCIATIONS

At the beginning of this research project in late1994, there was very little global activity in the area of airline baggage handler injury prevention and it was realised that support of industry groups would be needed. Accordingly, both the Australasian Airlines Ground Safety Council and the International Air Transport Executive (ARTEX) of the National Safety Council of America were asked to support this research project. Both organisations responded very favourably and their support of the project throughout was invaluable.

In 1995, ARTEX reconstituted its ergonomics sub-committee which had been dormant since the mid 1980's and gave this research project its full support and backing by appointing the author to the chairmanship of its ergonomics sub-committee. This helped generate momentum in the project and gave it optimum status for the reluctant airlines, aircraft manufacturers and aircraft ground support equipment manufacturers to take the project seriously.

To foster interest in the project, and in the issue of airline baggage handler injuries itself, in the period from early 1995 to 2000, twenty presentations were conducted as part of this project at aviation safety conferences around the world, and at the major jet transport aircraft manufacturers and aircraft ground support equipment manufacturers in Europe and USA (see Appendix No. 2 for details).

In the USA, the only interest in the matter prior to 1995 seemed to have been the ARTEX research (ARTEX 1981) which apparently had not been published. In Europe, only the Scandinavian airlines, had been investigating the problem, as described in Chapter 1.

In 1995, a series of meetings were organised by the author at the major aircraft manufacturers. Each meeting commenced with the presentation of the discussion paper (see Appendix No. 1) after which the attendees were asked their responses to the four research questions related to the manufacturers' prior awareness or experience of the baggage handler injury problem. Table 3.1 outlines the responses of the standard question sets put to the manufacturers' representatives at each meeting.

Table 3.1
The Initial Response of the Aircraft Manufacturers

Question	**Boeing, Seattle, USA**	**Airbus, Toulouse, France**	**McDonnell Douglas, Long Beach, USA**	**BAE Avro, Woodford, UK**	**Fokker, Amsterdam, Holland[30]**
Were they aware of the problem of manual handling injuries to airline baggage handlers?	NO	NO	NO	NO	NO
Were they taking any action to address the problem?	NO	NO	NO	NO	NO
Were they aware of any other organisations working on the baggage handling injury issue? [31]	NO[2]	NO[2]	NO[2]	NO[2]	NO[2]
Were they willing to review their aircraft baggage compartment designs?	NO	NO	NO	NO	NO
Would they participate in activities to help develop lasting solutions?	YES	YES	NO	YES	YES

Attendees Key:

Boeing: Chief Engineer Airplane Safety Engineering, Group Manager Safety Health and Environmental Affairs, Senior Airplane Safety Engineer, Manager Ground Operations Support, Manager B737 and B757 Engineering, Group Environmental Manager, Ground Support Equipment and Facilities Engineer

Airbus: Senior Interiors Design Engineer, Interiors Design Engineer and Customer Service Engineer

McDonnell Douglas: Senior Principal Specialist Design Assurance and Safety, Group Leader Aircraft Interiors Engineering, Interiors Systems Engineer and Senior Engineer Scientist Human Factors technology

BAE Avro: Assistant Chief Airframe Design Engineer, Senior Customer Engineer and Interiors Design Cell Leader

Fokker: Airport Compatibility Specialist and Interiors Engineer

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30 Meeting held at Sodehotel in Brussels, Belgium

31 While all manufacturers responded in the negative, all pointed to the *ACE* and *Sliding Carpet* systems as possible solutions since both were known to reduce the number of baggage handlers required to load an aircraft baggage compartment, thus theoretically reducing exposure to injury.

It was apparent that the issue of airline baggage handler injuries had not been previously raised with any of the aircraft manufacturers. Some of the senior representatives of Boeing and McDonnell Douglas were clearly sceptical, one even played down the issue in a subsequent communication *(Anderson (1995))*.

Also, it was obvious that the aircraft manufacturers had traditionally only interfaced with the maintenance, technical engineering and flight operations departments of their customer airlines and had little or no contact with the airports or OH&S departments. Accordingly, worker injury issues, other than flightcrew injuries, were hardly, if ever raised with the manufacturers by the airlines.

It was apparent that airline ground staff injuries were not viewed as a product liability issue for the manufacturers and no OH&S regulators had raised the issue with them before either.

None of the manufacturers envisaged solutions to the baggage handler injuries involving aircraft redesign, all claimed the costs of aircraft re-design would be too high and thought any solution lay elsewhere with ground equipment manufacturers or other third party solutions. Potential aircraft weight penalties for any solutions involving aircraft redesign were vigorously argued by all manufacturers, which were seen as commercially damaging. They all argued that increased weight from redesign would reduce aircraft performance and directly effect aircraft useability, especially at “hot and high” aerodromes.

There was consensus view expressed by all manufacturers that aircraft design would not change unless a critical mass of the customer airlines demanded change.

Airport terminal design was also clearly seen by all the manufacturers as the problem of airlines and airport authorities. No meaningful connection to the design of the aircraft baggage compartments and systems was made by any of the manufacturers at the time of these meetings in 1995.

All manufacturers pointed toward the retrofit systems, *ACE* and *Sliding Carpet* for narrow-body aircraft. Also, they felt containerisation was the solution to the problem for wide- body aircraft. Indeed, Airbus stressed that their A320 narrow-body aircraft was also offered with an optional container system, but only slightly more than 60% of the aircraft sold to that time had been containerised.

Notwithstanding the general negative response to the issue at these meetings, all manufacturers except McDonnell Douglas agreed to support this project and participate in finding solutions to the baggage handler injury problem. Boeing and Airbus agreed to fully participate in the ARTEX ergonomics sub-committee. All agreed to broker meetings with their relevant ground support equipment manufacturers, in particular *ACE* manufacturer Air Cargo Equipment and *Sliding Carpet* manufacturer, Scandinavian Bellyloading.

All manufacturers requested more definitive information on the magnitude of the baggage handler injury problem, especially in relation to costs. They were equally interested to gain an understanding of the mechanisms of injury, particularly in relation to aircraft and aircraft systems design.

Both Fokker and McDonnell Douglas took no further part in the project, both being declared bankrupt within 12 months of these meetings.

3.2 PHASE 2: SURVEY OF AIRLINE SAFETY PROFESSIONALS

The reported cost[32] of back injuries in the baggage handler work force of the sixteen organisations that provided useable cost, injury occurrence and exposure data in this part of the project collectively rose from $US 17,639,857 in 1992 to $US 23,697,170 in 1993 and dropped slightly to $US 21,710,953 in

[32] Airlines were requested to include all compensation, medical expenses and rehabilitation costs.

1994. The total number of baggage handler lost time back injuries in those companies rose from 1570 in 1992 to 2408 in 1993 and then remain almost unchanged at 2405 in 1994. Table 3.2 summarises the responses to the questions in Part A of the survey and includes the Lost Time Injury Frequency Rates (LTIFRs)[33] and the annual average cost per back injury calculated from the responses.

Table 3.2
The Back Injury Problem Quantified

	1992	1993	1994
No of Baggage Handlers	19430	30257	29099
Av. Hours Worked/ Person/Week	38.0	38.4	38.4
No of Lost Time Back Injuries	1570	2408	2405
Annual Cost ($US)	$17,639,857	$23,697,170	$21,710,953
Lost Time Injury Frequency Rate	42.5	41.5	43.5
Average Cost Per Back Injury ($US)	$11,236	$9841	$9027

Reported baggage handler numbers indicate the participating airlines almost doubled their baggage handling workforce between 1992 and 1993 and the reported injury numbers jumped proportionally. The injury rates remained almost constant. LTIFRs calculated from the respondent data were 42.5 for 1992, 41.5 for 1993 and 43.5 for 1994. Average cost per back injury reduced over the period from $US 11,236 in 1992 to $US 9,841 in 1993 and $US 9027 in 1994.

These results confirmed that back injuries were a significant burden on airlines and a problem of epidemic proportions.

In addition, the Safety Professionals were asked to rank the following workplaces in order from that which they considered most likely to be the site

[33] LTIFR was calculated per million hours worked, based on the data provided by the survey participants.

of a back injury, to those which they considered least likely. The work places were: Baggage check-in; Baggage make-up room; Inside narrow body aircraft; Inside wide body aircraft bulk hold, and; Outside aircraft on the ramp. Table 3.3 shows that ten of the sixteen respondents felt that the highest injury risk location to be "Inside Narrow Body Aircraft.

With regard to which baggage handling tasks were considered most likely to cause a back injury, the task most commonly identified as a significant problem was "*Stacking Baggage inside the Baggage Compartments of Narrow Body Aircraft*". Fourteen of the sixteen respondents identified it as one of their top five high risk baggage handling tasks (see Table 3.4). This was closely followed by "*Pushing Baggage from the Doorway into the Baggage Compartment of Narrow Body Aircraft*" and "*Transferring Baggage from a Trailer directly into a Narrow Body Aircraft*", both with eleven responses each. It is also of interest that the task ranked fourth most likely to cause a back injury, with nine responses, was "*Pushing and Pulling Containers and Pallets inside Wide Body Aircraft*", since this task was only required to take place after an aircraft's built-in mechanical transfer systems were unserviceable, clearly bringing into question the effectiveness of those mechanical systems.

Table 3.3
Manual Handling Locations Ranked
MOST Likely to Cause Injury
(n=16)

Location	**frequency**
Baggage Check-in	1
Baggage Make-up Room	2
Inside Narrow Body Aircraft Baggage Compartments	10
Inside Wide Body Aircraft Bulk Hold	0
Outside Aircraft On the Tarmac	3

All but one of the Safety Professionals surveyed in this study indicated that baggage handlers in their organisations were required to lift baggage weighing in excess of 32kgs(70lbs).

Also, since a number of airline baggage handlers around the world were known to be using various types of back support belts, the Safety Professionals were asked to indicate whether their organisations had used such belts as a measure to control back injuries in baggage handlers. However, there was no conclusive outcome. Only two respondents reported that back support belts were used in their airlines. One of these indicated that introduction of the belts had made no difference to the instance of baggage handler back injuries consistent with the predominant theme from other studies in the literature discussed in Chapter 1, while the other claimed a 60% improvement in injury occurrence. However, this sole positive result contradicts the majority of the literature, opposes the outcome that may be expected given the principles of the hierarchy of hazard controls and further details of the case would be needed to confirm the scientific merit of the claims.

Table 3.4
Manual Handling Tasks Ranked MOST Likely to Cause Injury
n=80

Tasks	Frequency
Lifting Baggage on or off Scales at Check-in	2
Loading Baggage onto Trailers in the Baggage Make-up Room	8
Loading Containers in the Baggage Room	6
Unloading Baggage Trailers in the Baggage Room	3
Unloading Containers in the Baggage Room	1
Pushing and Pulling Loaded Baggage Trailers, Containers and Pallet Dollies	7
Transferring Baggage from a Trailer to Mobile Belt Positioned at the Aircraft	2
Transferring Baggage from a Trailer Directly Into an Aircraft through the Cargo Door	11
Pushing Baggage from the Doorway into the Baggage Compartment of Narrow Body Aircraft	11
Stacking Baggage Inside the Baggage Compartment of Narrow Body Aircraft	14
Pushing and Pulling Containers and pallets Inside Wide Body Aircraft	9
Stacking Baggage in the Bulk Hold of Wide Body Aircraft	6

The industry Safety Professionals were also asked what impact “back care” training had on the instance or severity of back injuries in their companies. It is significant that while twelve of the sixteen respondents to the question reported that such training was provided to staff, only two reported that the training had any effect on their back injury rates.

A consensus of reported poor outcomes due to training interventions would also seem to be consistent with the hierarchy of hazard control theory that these administrative process maybe les reliable than the higher order engineering solutions.

Eleven respondents reported that their airlines used ground equipment to reduce manual handling risk to baggage handlers. However, only one reported that use of such equipment had resulted in an improvement in injury occurrence and then the reported improvement was only “10%”, hardly a significant percentage.

The benefits of mechanical solutions to manual handling problems have long been recognised and the literature includes a plethora of studies and opinion papers to that effect. However, it seems likely that many in the airline industry would identify the existing aircraft ground equipment as solutions to the baggage transfer problem rather than an injury prevention solution. Ground equipment clearly solves the problems created by the distance baggage has to transferred on airports. However, mechanical devices such as belt loaders and pallet loaders also can have a positive impact on injury occurrence, as detailed in Chapter 1, provided they are utilised and maintained correctly.

It was of interest to note that none of the organisations surveyed had provided any mechanical lifting aids to assist with baggage handling tasks either within airport terminals or within aircraft. Clearly ground equipment has been perceived as solutions to the logistics problems faced by airlines but not for the manual handling injury risk faced daily by their baggage handlers.

Only six respondents reported that their organisations' had reviewed the design of terminal buildings in an effort to reduce baggage handler injury occurrence, and just one person was able to suggest that an injury rate reduction had occurred.

On the subject of possible solutions to the back injury problem, the airline safety managers supported a range of suggested measures, as Table 3.5 shows.

The results of this phase of the research were published in the peer reviewed journal "*Safety Science Monitor*"[34]. A copy of the paper (*Dell (1997)*) has been included at Appendix No. 20.

Table 3.5
Solutions to the Baggage Handler Back Injuries
n=16

Solution	**Frequency**
Introduction of limits on baggage weights and size	16
Provision of mechanical lifting assistance devices	14
Development of better training of baggage handlers	14
Introduction of in-plane stacking systems for narrow-body aircraft	9
Re-design of existing baggage systems to account for ergonomic risk	9
Introduction of baggage handler fitness and warm up programs	8
Introduction of better rostering and job rotation	3
Improved equipment maintenance by airlines	2
Improved work rate and task control by airlines	2

The airline safety professionals seem to be willing to attempt any intervention if there's a chance of improvement. Perhaps not a scientifically based methodology, but one perhaps evolved from the desperation of being unable to stem the injury tide. The desire to solve the problem by limiting the weight of baggage has been shown by *Culvenor (2004)* to be at best, very optimistic.

[34] The paper is also available online at http://www.monash.edu.au/muarc/IPSO/vol1/issue3/vol1iss3.htm

Indeed, the practical limitations on achieving this solution as desecribed in Chapter 1 would suggest its impossible. Also, it seems the lesson has yet to be learnt that better training helps little if the manual handling demands, such as are experienced in baggage handling, are so far above the accepted tolerance levels suggested in literature and in the various ergonomic models.

3.3 PHASE 3: SURVEY OF AIRLINE BAGGAGE HANDLERS OPINION ON THE CAUSES AND PREVENTION OF BACK INJURIES

Baggage handlers from the following organisations participated in the study: Aerolineas Argentinas - Argentina, Austral Airlines - Argentina, Delta Airlines – Germany, Delta Airlines – USA, Lufthansa - Germany, Northwest Airlines – USA, Midwest Express USA, Qantas Airways– Australia, Scandinavian Airline System - Scandinavia, Service Master - USA, CLT Aviation - USA.

Several airlines contacted the writer to advise they would not be able to participate because the industrial climate in the baggage handling area was such that conduct of the survey would be prejudicial to their operations. This applied to Ansett Airlines in Australia, Air New Zealand, Air Canada, Sabena Airlines in Belgium, KLM in Holland, United Airlines in USA, British Airways and Virgin Atlantic Airlines in the UK. Many others failed to participate after initially indicating that they would do so. No reasons for failure to participate were forthcoming, despite several attempts to contact by the writer, from over fifteen organisations.

However, a total of 156 baggage handlers, 148 males and 8 females, participated in the study. Their baggage handling experience ranged from 6 months to 32 years with the average being 10.6 years. The ages of respondents at their last birthday ranged from 17 to 62 years with the average age of the group of 36.3 years.

Back Injury Experience

Seventy-two (46%) of the baggage handlers reported that they had experienced a back injury while handling baggage in the past (see Table 3.6). Of those, forty (55%) felt that their back injuries reduced their ability to carry out the work and 43 (60%) reported that the injury had recurred at least once since the first occasion.

Table 3.6
Baggage Handler Opinions: Personal Injury Experience
n=156

QUESTION	Yes	No	N/R	n
Have you personally experienced a back injury while handling baggage?	72	84	0	156
Has the Back Injury Reduced Your Ability to Handle Baggage?	40	32	0	72
Has the injury recurred since the first occasion?	43	29	0	72

In response to the question “How often do you experience back pain when handling baggage”, one hundred and ten (71%) of the baggage handlers reported experiencing back pain more than once in the past. Twenty-seven (17%) reported having back pain daily, twenty-four (15%) reported having back pain weekly, eighteen (12%) monthly and forty-one (26%) seldom.

Opinions Related to Back Injury Causation

There was considerable consensus of opinion amongst baggage handlers on two issues related to back injury causation, namely which workplace was likely to cause most back injuries and whether heavy baggage was a significant back injury risk.

Seventy percent (110) of baggage handlers felt that the workplace likely to cause most back injuries was “Inside *Narrow-Body Aircraft Baggage Compartments*” (see Table 3.7 and examples at Figures 1.8 & 1.9 in Chapter 1). Baggage check-in was the next most common response, although with only 13 (8%) of the baggage handlers suggesting it was the location likely to cause most injuries. Seven percent (11) felt the workplace most likely to cause injuries was "*Outside the Aircraft on the Tarmac*", six percent (9) felt it was in the "*Baggage Sorting Room*" and a further six percent felt it was "*Inside Wide Body Aircraft Bulk Holds*".

Eighty-nine percent (139) of the baggage handlers reported that they were required to lift baggage over 32kg (70lb) and 141 (90%) considered such heavy baggage to be a significant injury risk.

Table 3.7 **Baggage Handler Opinion: Workplace Likely To Cause Most Back Injuries**	**n=156**
Inside Narrow Body Aircraft Baggage Compartments	110
Baggage Check-in	13
Outside Aircraft On the Tarmac	11
Baggage Sorting Room	9
Inside Wide Body Aircraft Bulk Hold	9
No Response	4

Table 3.8 summarises baggage handler responses to a range of questions regarding which manual handling tasks were considered to cause back injuries.

The baggage handling tasks within the narrow body aircraft, "*Pushing Baggage from Doorway into Narrow Body Compartment*" and "*Stacking Bags Inside Narrow Body Baggage Compartment*", were considered likely to cause back injuries by the most respondents (136 and 135 respectively). "*Transferring Baggage From Baggage Trailers Directly Into The Aircraft*" was the task next most considered likely to cause back injuries (131), followed by "*Pushing and Pulling Loaded Containers*" (129).

Table 3.8

Baggage Handler Opinions:
Manual Handling Tasks Likely To Cause Back Injuries

n=156

TASK	LIKELY	UNLIKELY	N/R[35]
Pushing Bags from Doorway into Narrow Body Compartment	136	18	2
Stacking Bags Inside Narrow Body Baggage Compartment	135	16	5
Transferring Bags from Trailer Directly into Aircraft	131	21	4
Pushing & Pulling Loaded Trailers	129	25	2
Pushing Containers Inside Wide Body Aircraft (Systems U/S)	118	27	11
Stacking Baggage Inside Wide Body Aircraft Bulk Holds	113	30	13
Loading Bags onto Trailers in the Baggage Room	107	47	2
Loading Containers in Baggage Room	104	42	10
Transferring Bags from Trailer to Mobile belt	103	49	4
Unloading Containers in the Baggage Room	101	44	11
Unloading Trailers in the Baggage Room	93	61	2
Lifting Baggage on & off Conveyors	69	83	4

Pushing containers inside wide body aircraft when the mechanical loading systems were unserviceable was thought likely to cause back injury by seventy six percent (118) of respondents, and stacking baggage inside wide body aircraft bulk holds (see for example Figure 1.12) was considered a back injury risk by seventy two percent (113) of the baggage handlers.

It is of interest that "*Lifting Baggage On And Off Conveyors*" was the only manual handling task that a majority (53% (83)) of the baggage handlers felt was *not* an injury risk.

Opinions Concerning Back Injury Prevention: Engineering Solutions

In response to the survey questions concerning the design of existing baggage sorting rooms, only slightly more than half, fifty-six percent (88) of the baggage handlers felt that the design of baggage sorting rooms made their job easier. The heights of conveyor belts were considered adequate by only fifty-two percent (82) of respondents.

Slightly more than one third (53) of the baggage handlers reported their airlines had installed stacking systems in the baggage compartments of their narrow body aircraft. However, nearly all of those baggage handlers (47) felt the stacking systems made baggage handling easier and reduced exposure to back injuries. Interestingly, all of the 53 baggage handlers whose airlines had fitted stacking systems preferred loading aircraft with a stacking system fitted over loading one without a stacking system installed.

Table 3.9 summarises baggage handler responses concerning possible engineering or redesign solutions to the back injury problem

Development of in-plane baggage and cargo stacking systems was the most popular redesign solution. One hundred and twenty two (78%) of the baggage handlers felt that this was a viable method of reducing the risk of back injury in the aircraft loading task. The second most popular engineering solution was to redesign baggage handling systems, supported by 111 (71%) of the baggage handlers. Although all engineering redesign solutions suggested in the survey (see Appendix No. 4) were supported by a majority of baggage handlers, provision of mechanical assistance devices, introduction of robotics to

[35] Nil Response

eliminate manual handling and aircraft baggage compartment redesign were favoured the least (93: 59%, 89: 57% and 78: 50% respectively).

Table 3.9
Baggage Handler Opinions: Engineering /Re-Design Solutions
n=156

SOLUTIONS	Yes	No	N/R
Develop In-plane Baggage & Cargo Stacking Systems	122	27	7
Redesign Baggage Handling Systems to Reduce Injury Risk	111	41	4
Provide Mechanical Assistance Devices for Lifting Baggage	93	49	14
Introduce Robotics to Eliminate Manual Handling	89	60	6
Redesign Aircraft Baggage Compartments	78	69	9

Opinions concerning Back Injury Prevention: Administrative Solutions

The most popular procedural intervention amongst respondents, and the most popular over all, was the possible introduction of “heavy” tags to warn staff of the increased injury risk presented by those bags. One hundred and forty (90%) of the baggage handlers supported this potential intervention. However, as detailed previously, this solution has been shown in the recent study of baggage handling injury interventions involving a trial of weight tags, *Korkmaz et al (2006)* found these weight warning tags made no difference to the risk of injury.

Almost as popular with 138 positive responses, was the potential solution of improving baggage handler training.

Better maintenance of equipment was the third most preferred solution (121 positive responses). “Introduction of Warm-up Exercises“ and “Improvement In The Quality Of Supervision” (98 and 67 positive responses respectively) were the least favoured solutions, the latter being the only suggested solution where a majority support was not achieved.

Table 3.10 summarises the baggage handlers' opinions concerning possible administrative or procedural solutions to back injury problem.

Table 3.10
BAGGAGE HANDLER OPINIONS:
PROCEDURAL AND ADMINISTRATIVE SOLUTIONS
n=156

SOLUTIONS	Yes	No	N/R
Put "Heavy" Tags on Heavy Baggage to Warn Staff	140	3	13
Introduce Better Baggage Handler Training	138	14	4
Better Maintenance of Equipment	121	27	8
Introduce Better Baggage & Cargo Acceptance Procedures	120	23	13
Better Rostering of Staff to Meet Work Demands	119	31	6
Educate the Public Concerning Injury Risks to Baggage handlers	118	26	12
Should a Lower Baggage Weight Be Enforced	114	28	14
Slow the Baggage Handling Process Down	104	48	4
Make Passengers Re-pack Heavy Baggage to Reduce Weight	101	42	13
Introduce Back Support Belts	100	47	9
Introduce Warm-up Exercises	98	52	6
Improve Quality of Supervision	67	81	7

Baggage Handler Experience and Opinion Concerning Back Support Belts

Since some airlines and handling companies had required or permitted the use of back support belts in the past, baggage handlers in this survey were asked a number of questions regarding the their use.

Only sixty-three (40%) of the baggage handlers surveyed had worn back support belts and ten of those had suffered a back injury while wearing the support. A majority (93, 59%) of baggage handlers believed that back support belts improve a wearers ability to carry out baggage handling tasks, ninety-four (94, 60%) consider back support belts prevent lost time back injuries and eighty-six (55%) believed back supports should be worn for all lifting tasks. Only thirteen (8%) baggage handlers considered that wearing back supports negated the need for lifting technique training.

Table 3.11 summarises the baggage handlers' opinions concerning the use of back support belts.

Table 3.11
Baggage Handler Opinions: Back Support Belts
n=156

QUESTION	Yes	No	N/R
Have you personally worn a back support belt to help prevent back injuries?	63	90	3
Have you experienced a back injury while wearing a back support belt?	10	123	23
Do back support belts improve a wearers' ability to do baggage handling tasks?	93	52	11
Back support belts help prevent lost time back injuries?	94	52	10
Back support belts should be worn for all lifting tasks	86	60	10
Back support belts make lifting technique training unnecessary	13	133	10
If you wear a back support belt at work, you must wear it when lifting at home	66	78	12

As Table 3.12 shows, training as a means to reduce the risks related to baggage was supported by the majority of baggage handlers in this study.

However, nearly all (94%) of the baggage handlers felt that training needed to include techniques for lifting with restricted postures in confined spaces.

Eighty-two percent (129) of the baggage handlers who participated in this study felt that back care training will help to prevent lost time back injuries, and seventy-eight percent (123) believed it will enhance baggage handlers' ability to carry out their work.

Table 3.12
Baggage Handler Opinions: Training

n=156

QUESTION	**Yes**	**No**	**N/R**
Training must include techniques for lifting in restricted postures/confined spaces?	145	9	2
Back care training will help prevent lost time back injuries?	129	25	2
Back care training improves baggage handler ability to conduct handling tasks?	123	30	1
Warm up exercises should form part of baggage handlers' daily routine	105	48	2
Lifting technique (back straight/knees bent) training benefits baggage handlers	104	48	11

The results of this phase of the research were published in the peer reviewed journal "*Safety Science Monitor*"[36] and an edited version was published by the Flight Safety Foundation in Washington DC in their refereed journal *"Airport Operations"*. A copy of that paper (*Dell (1998))* has been included at Appendix No. 21.

[36] Available online at http://www.monash.edu.au/muarc/IPSO/vol2/issue2/vol2iss2.htm

3.4 PHASE 4: LABORATORY TRIALS AND ERGONOMIC ANALYSIS OF *ACE* AND *SLIDING CARPET* NARROW-BODY AIRCRAFT BAGGAGE SYSTEMS

This phase of the study involved the simulation of the two commercially available baggage systems for narrow-body aircraft, *ACE* and *Sliding Carpet*. It also simulated a B737 aircraft baggage compartment without either system fitted (“No System” configuration). The postures adopted by the subjects during the trial sequences provided an indication of any differences in the risk of a back injury resulting from using the three different baggage compartment configurations, namely *Ace*, *Sliding Carpet* and “No System”.

To identify any postural differences which may indicate a variation in the risk of a back injury caused by stacking baggage in the different baggage compartment configurations, video footage of each trial was simultaneously recorded by three cameras positioned at 90^{o} to one another around the mock-up, as described in Chapter 2.

Analysis of the 3D Video of Working Postures Adopted by Baggage Handlers

Since all methods of analysis of the 3D video data included some level of subjectivity, in order to ensure a high level of confidence in the outcomes of this phase of the research, three methods of analysis were applied: Biomechanical modelling, direct measurement of baggage handler reach and trunk rotation and the ergonomists opinions ratings.

As explained in Chapter 2, for valid statistical analyses using multivariate test methods, ANOVA, MANOVA and mixed linear models, the data were grouped into two data sets and treated separately. The first, the biomechanical data set, contained the data from the Michigan 3D Program and the direct measurement of baggage handler reach and trunk rotation. The second data set contained the ergonomists opinion data. The following details the findings for each data set.

Data Set 1: Biomechanical Data

The output of the Michigan 3D Program for each modelled posture was an Excel spreadsheet containing seventy eight parameters related to all aspects of the modelled posture. Successive modelling of multiple postures, as was the case in this analysis, resulted in accumulative compilation of the spreadsheet so that once all postures had been modelled, all the data resided in the one spreadsheet with data from each posture on a separate line of the spreadsheet. Appendix No. 22 contains all the output data for the eighty-one postures modelled using the Michigan Program in this study.

As described in Chapter 2, the two output measures from the Michigan Program selected for analysis in this study were the L4 L5 and L5 S1 disc compression data.

It is of interest that all of the postures adopted by the baggage handlers in this study, based on the output data from the Michigan 3D program showed disc compression forces that, while not extreme, did represent significant spinal disc loading and back injury risk. *McGill (2002)* suggested that overload damage to the lumbar spine begins at around 7000N compression, dependent on age and fitness. Also, NIOSH in their guide for manual lifting (*NIOSH (1981)*) which included equations for estimating acceptable and maximum limits for manual handling tasks suggested L4L5 disc loadings over 6376N were hazardous to most workers and those over 3433N required ergonomic or administrative intervention because they were potentially hazardous. Maximum disc compression loadings estimated by modelling in this study were found to be in the 3000N to 6800N range. The accumulative effect of these loadings over the many lifting cycles experienced by baggage handlers clearly represents a significant low back injury risk.

However, establishing that the baggage handling tasks in the baggage compartment of narrow-body aircraft were a high injury risk was not the principal objective of the analysis. Rather it was to use any differences observed in the measures of baggage handlers' postures to indicate whether there were differences in injury risk between the three baggage compartment configurations *ACE, Sliding Carpet* and *"No System"*.

Appendix No. 23 shows the L4 L5 disc compression data from the Michigan 3D Program for the eighty-one postures sorted by bag position and mock-up configuration. Table 3.13 shows the three population means and standard deviations for the L4 L5 disc compression data. Figure 3.1 shows the plots of these data and the differences between the results for the three mock-up configurations *ACE, Sliding Carpet* and *"No System"*.

Table 3.13
L4 L5 Disc Compression Forces[37]
(Newton)

Measure	ACE	SC	NS
Mean	-6202.40	-5501.49	-5239.90
SD	585.09	851.30	513.70
For each set n=27; nine subjects x 3 bag positions			

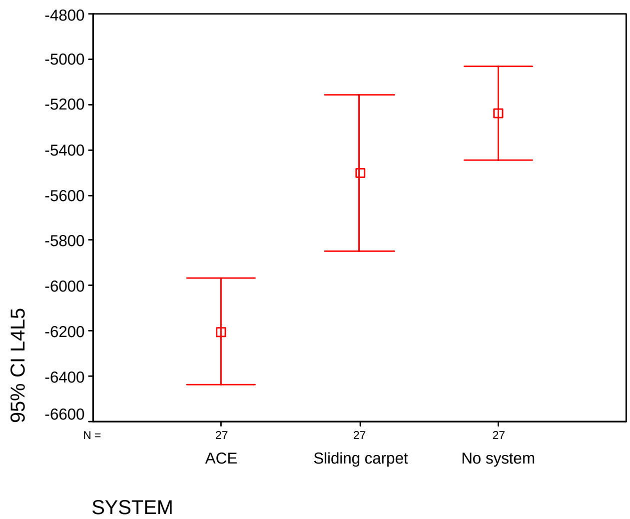

Figure 3.1
Comparison of L4L5 disk compression forces
(Newton)

[37] Negative values represent direction of compression force in relation to a datum used by the Michigan Program to aggregate muscle forces on the disc (see *Michigan (1998)*). Negative values do not

Since negativity (-) of the disc force measures of the Michigan Program denotes direction of the force and not a less than zero result, clearly the results for the *ACE* system indicates higher disc forces than either *Sliding Carpet* or *"No-System"* which substantially overlap with each other.

Appendix No. 24 shows the L5S1 disc compression data from the Michigan Program for the eighty-one postures sorted by bag position and mock-up configuration. Table 3.14 shows the three population means and standard deviations for the L5S1 disc compression data.

Table 3.14
L5 S1 Disc Compression Forces
(Newton)

Measure	ACE	SC	NS
Mean	4432.95	3313.05	3627.50
SD	1503.99	1690.54	1254.94
For each set n=27; nine subjects x 3 bag positions			

Figure 3.2 shows the plots of these L5S1 data. The data shows that there were noticeably higher L5S1 disc compression forces on average for *ACE* than either *Sliding Carpet* or *"No-System"* .

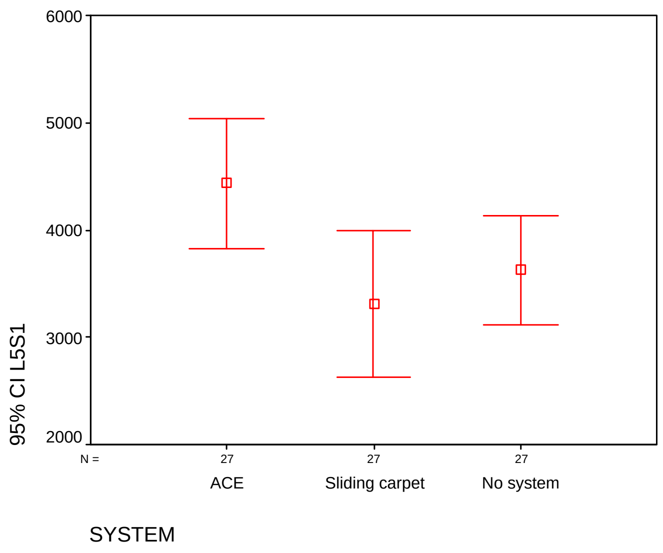

Figure 3.2
Comparison of L5S1 disk compression forces

The measurements of the nine baggage handlers' maximum Reach and Trunk Rotation, taken from the twenty-seven still frame images (see Appendix No. 10) are at Appendix No. 25. The population means and standard deviations for the three data sets *Ace*, *Sliding Carpet* and "No System", for the Reach and Trunk Rotation data sets are shown in Tables 3.15 and 3.16 respectively.

Table 3.15 Direct Measurement: Reach (centimetres)			
Measure	ACE	SC	NS
Mean	113.21	95.11	91.61
SD	9.40	15.50	13.78
For each set n=27; nine subjects x 3 bag positions			

Figure 3.2 shows the plot of the Reach data which indicates that the baggage handlers on average were required to reach noticeably further when stacking into the *ACE* mock-up configuration than when stacking in either *Sliding Carpet* or *"No-System"* populations.

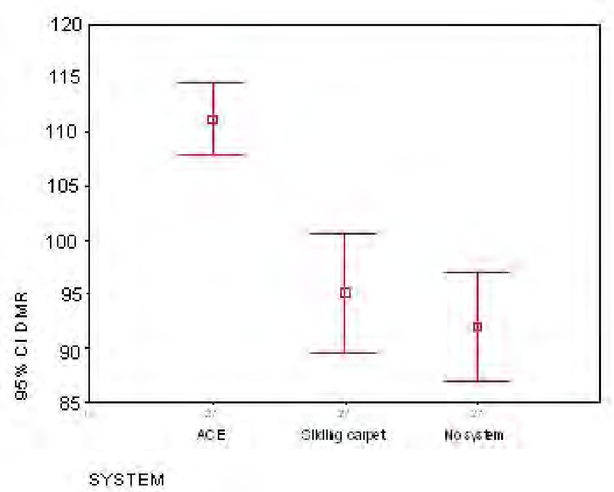

Figure 3.3
Comparison of Baggage Handlers Reach

Table 3.16 Direct Measurement: Trunk Rotation (Degrees of rotation)			
Measure	ACE	SC	NS
Mean	31.89	35.85	33.63
SD	17.37	17.23	18.66
For each set n=27; nine subjects x 3 bag positions			

In contrast, Figure 3.4 which depicts the trunk rotation data shows that there was little difference in baggage handlers' trunk rotations on average when stacking baggage into the *ACE* , *Sliding Carpet* and *"No-System"* system configurations.

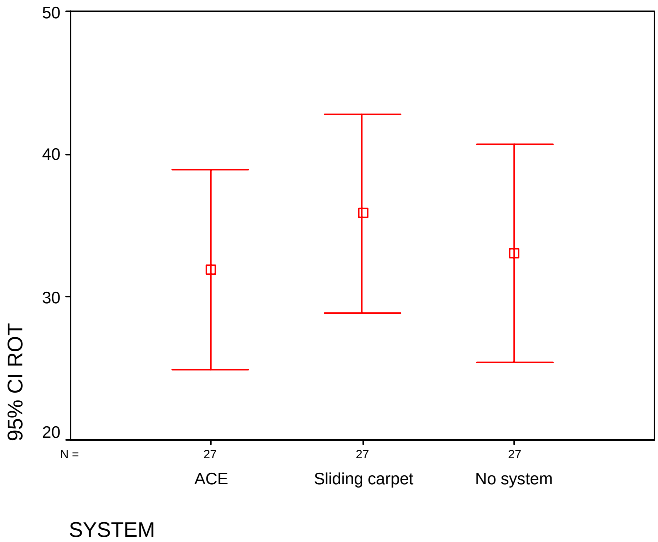

Figure 3.4
Comparison of Baggage Handlers Trunk Rotation

Analysis of Variance Tests Across all the Measures in Data Set 1: L4L5 Disc Compression, L5S1 Disc Compression, Baggage Handler Reach and Baggage Handler Trunk Rotation

Table 3.17 shows the results of the analysis of variance tests that were conducted across all of the four measures L4L5 Disc Compression, L5S1 Disc Compression, Baggage Handler Reach and Baggage Handler Trunk Rotation. The test was conducted using each measure as the dependent variable sequentially.

When the test was conducted with the L4L5 disc compression data as the dependent variable, the test returned significant differences between the *ACE* and *Sliding Carpet* baggage compartment configurations at the 95% (0.05) confidence level. Similar significant differences were also returned at the 95% (0.05) confidence level, between the *ACE* and “No-system” based on the L4L5 disc compression data. However, there was no significant difference returned between *Sliding Carpet* and “No-system” based on the L4L5 disc compression data.

Since the mean L4L5 disc compression force for *ACE* was 6202.40N and for *Sliding Carpet and* “No System” were 5501.40N and 5239.90 respectively, it can be assumed from these results that postures adopted by baggage handlers stacking baggage into *ACE* generated statistically significantly higher L4L5 disc compression forces and therefore the postures represented a higher risk of L4L5 injury than when stacking baggage into either *Sliding Carpet* or into a baggage compartment with no system fitted.

Table 3.17
Univariate Analysis of Variance:
Dependent Variable L4L5 Disc Compression Force
(Newton)

Multiple Comparisons

Dependent Variable: L4L5
Bonferroni

(I) SYSTEM	(J) SYSTEM	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
ACE	Sliding carpet	-700.9089*	164.12189	.000	-1103.2043	-298.6135
	No system	-962.4974*	164.12189	.000	-1364.7928	-560.2020
Sliding carpet	ACE	700.9089*	164.12189	.000	298.6135	1103.2043
	No system	-261.5885	164.12189	.346	-663.8839	140.7069
No system	ACE	962.4974*	164.12189	.000	560.2020	1364.7928
	Sliding carpet	261.5885	164.12189	.346	-140.7069	663.8839

Based on observed means.
*. The mean difference is significant at the .05 level.

Table 3.18 shows the results of the analysis of variance with the L5S1 disc compression as the dependent variable. With L5S1 disc compression data as the dependent variable, the ANOVA also returned significant differences between the *ACE* and *Sliding Carpet* baggage compartment configurations at the 95% (0.05) confidence level. Similar significant differences were also returned at the 95% (0.05) confidence level, between the *ACE* and "No-system" based on the L5S1 disc compression data. However, there was also no significant difference between *Sliding Carpet* and "No-system" L4L5 disc compression data.

The mean L5S1 disc compression force for *ACE* was 4432.95N and for *Sliding Carpet* and "No System" were 3313.05N and 3627.50 respectively (see Table 3.17). Accordingly, it can be assumed from these results that postures adopted by baggage handlers stacking baggage into *ACE* generate statistically significantly higher L5S1 disc compression forces and therefore the postures represented a higher risk of L4L5 injury than when stacking baggage into either *Sliding Carpet* or into a baggage compartment with no system fitted.

Table 3.18
Univariate Analysis of Variance:
Dependent Variable L5S1 Disc Compression Force
(Newton)

Multiple Comparisons

Dependent Variable: L5S1
Bonferroni

(I) SYSTEM	(J) SYSTEM	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
ACE	Sliding carpet	1119.8912*	351.46112	.006	258.3900	1981.3923
	No system	805.4428	351.46112	.075	-56.0584	1666.9439
Sliding carpet	ACE	-1119.8912*	351.46112	.006	-1981.3923	-258.3900
	No system	-314.4484	351.46112	1.000	-1175.9496	547.0527
No system	ACE	-805.4428	351.46112	.075	-1666.9439	56.0584
	Sliding carpet	314.4484	351.46112	1.000	-547.0527	1175.9496

Based on observed means.
*. The mean difference is significant at the .05 level.

Table 3.19 shows the results of the ANOVA with Baggage Handler Reach as the dependent variable. With Baggage Handler Reach as the dependent variable, the ANOVA also returned significant differences between the *ACE* and *Sliding Carpet* baggage compartment configurations at the 95% (0.05) confidence level. Similar significant differences were also returned at the 95% (0.05) confidence level, between the *ACE* and "No-system" based on the Baggage Handler Reach data. However, there was also no significant difference between *Sliding Carpet* and "No-system" Baggage Handler Reach data.

Table 3.19
Univariate Analysis of Variance:
Dependent Variable Baggage Handler Reach
(centimetres)

Multiple Comparisons

Dependent Variable: DMR
Bonferroni

(I) SYSTEM	(J) SYSTEM	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
ACE	Sliding carpet	3.24*	.553	.000	1.88	4.59
	No system	3.86*	.553	.000	2.51	5.22
Sliding carpet	ACE	-3.24*	.553	.000	-4.59	-1.88
	No system	.63	.553	.784	-.73	1.98
No system	ACE	-3.86*	.553	.000	-5.22	-2.51
	Sliding carpet	-.63	.553	.784	-1.98	.73

Based on observed means.

*. The mean difference is significant at the .05 level.

Since the mean score for ACE was 113.21 cm and the means for *Sliding Carpet and* “No System” were 95.11cm and 91.61cm respectively (see Table 3.20), it can be assumed from these results that postures adopted by baggage handlers stacking baggage into ACE generated statistically significantly greater reach distances than when stacking baggage into either *Sliding Carpet* or into a baggage compartment with no system fitted.

Given that reaching while lifting has previously been identified as a major back injury risk factor and the higher the moment of the load, that is the greater the distance of the load from the spine, the higher the risk (see for example McGill (2002): p96), this comparison of reach distances and associated postures suggests there is a significantly higher risk of back injury for baggage handlers stacking baggage into an *ACE* system compared to stacking baggage into either *Sliding Carpet* or into a baggage compartment with no system fitted.

In contrast, Table 3.20 shows the results of the ANOVA with Baggage Handler Trunk Rotation as the dependent variable. In this case, the ANOVA returned no significant difference between the *ACE*, *Sliding Carpet* and “No-system” mock-up configurations.

Table 3.20
Univariate Analysis of Variance:
Dependent Variable Baggage Handler Trunk Rotation
(Degrees of Rotation)

Multiple Comparisons

Dependent Variable: ROT
Bonferroni

(I) SYSTEM	(J) SYSTEM	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
ACE	Sliding carpet	-3.96	4.478	1.000	-14.94	7.01
	No system	-1.19	4.478	1.000	-12.16	9.79
Sliding carpet	ACE	3.96	4.478	1.000	-7.01	14.94
	No system	2.78	4.478	1.000	-8.20	13.75
No system	ACE	1.19	4.478	1.000	-9.79	12.16
	Sliding carpet	-2.78	4.478	1.000	-13.75	8.20

Based on observed means.

Mixed Model Analyses Across all the Measures: L4L5 Disc Compression, L5S1 Disc Compression, Baggage Handler Reach and Baggage Handler Trunk Rotation Data.

Table 3.21 shows the results of the mixed model analysis of variance with L4L5 disc compression force as the dependent variable. The test also returned significant differences between the *ACE* and *Sliding Carpet* configurations at the 95% (0.05) confidence level. The test also returned significant differences at the 95% (0.05) confidence level between the *ACE* and “No-system” mock-up configurations. However, there was no significant difference returned between *Sliding Carpet* and “No-system”.

Table 3.21
Mixed Model Analysis of Variance:
Dependent Variable L4L5 Disc Compression
(Newton)

Pairwise Comparisons[b]

(I) SYSTEM	(J) SYSTEM	Mean Difference (I-J)	Std. Error	df	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
ACE	Sliding carpet	-700.909*	164.122	72	.000	-1103.204	-298.613
	No system	-962.497*	164.122	72	.000	-1364.793	-560.202
Sliding carpet	ACE	700.909*	164.122	72	.000	298.613	1103.204
	No system	-261.589	164.122	72	.346	-663.884	140.707
No system	ACE	962.497*	164.122	72	.000	560.202	1364.793
	Sliding carpet	261.589	164.122	72	.346	-140.707	663.884

Based on estimated marginal means
*. The mean difference is significant at the .05 level.
a. Adjustment for multiple comparisons: Bonferroni.
b. Dependent Variable: L4L5.

Table 3.22 shows the results of the mixed model analysis of variance with L5S1 disc compression force as the dependent variable. The test also returned significant differences between the *ACE* and *Sliding Carpet* configurations at the 95% (0.05) confidence level. The test also returned significant differences at the 95% (0.05) confidence level between the *ACE* and “No-system” mock-up configurations. However, there was no significant difference returned between *Sliding Carpet* and “No-system”.

Table 3.22
Mixed Model Analysis of Variance:
Dependent Variable L5S1 Disc Compression Force
(Newton)

Pairwise Comparisons[b]

(I) SYSTEM	(J) SYSTEM	Mean Difference (I-J)	Std. Error	df	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
ACE	Sliding carpet	1119.891*	351.461	72	.006	258.390	1981.392
	No system	805.443	351.461	72	.075	-56.058	1666.944
Sliding carpet	ACE	-1119.891*	351.461	72	.006	-1981.392	-258.390
	No system	-314.448	351.461	72	1.000	-1175.950	547.053
No system	ACE	-805.443	351.461	72	.075	-1666.944	56.058
	Sliding carpet	314.448	351.461	72	1.000	-547.053	1175.950

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Adjustment for multiple comparisons: Bonferroni.

b. Dependent Variable: L5S1.

Table 3.23 shows the results of the mixed model analysis of variance with Baggage Handler Reach as the dependent variable. This test also returned significant differences between the *ACE* and *Sliding Carpet* configurations and between the *ACE* and “No-system” mock-up configurations at the 95% (0.05) confidence level. However, there was also no significant returned difference between *Sliding Carpet* and “No-system”.

.Table 3.23
Mixed Model Analysis of Variance:
Dependent Variable Baggage Handler Reach
(centimetres)

Pairwise Comparisons[b]

(I) SYSTEM	(J) SYSTEM	Mean Difference (I-J)	Std. Error	df	Sig.[a]	95% Confidence Interval for Difference[a]	
						Lower Bound	Upper Bound
ACE	Sliding carpet	3.237*	.553	72	.000	1.881	4.593
	No system	3.863*	.553	72	.000	2.507	5.219
Sliding carpet	ACE	-3.237*	.553	72	.000	-4.593	-1.881
	No system	.626	.553	72	.784	-.730	1.981
No system	ACE	-3.863*	.553	72	.000	-5.219	-2.507
	Sliding carpet	-.626	.553	72	.784	-1.981	.730

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Adjustment for multiple comparisons: Bonferroni.

b. Dependent Variable: DMR.

Table 3.24 shows the results of the mixed model analysis of variance with Baggage Handler Trunk Rotation as the dependent variable. The test indicated there was no significant difference between the *ACE*, *Sliding Carpet* and “No-system” baggage handler trunk rotation data.

Table 3.24
Mixed Model Analysis of Variance:
Dependent Variable Baggage Handler Trunk Rotation
(Degrees of Rotation)

Multiple Comparisons

Dependent Variable: ROT
Bonferroni

(I) SYSTEM	(J) SYSTEM	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
ACE	Sliding carpet	-3.96	4.478	1.000	-14.94	7.01
	No system	-1.19	4.478	1.000	-12.16	9.79
Sliding carpet	ACE	3.96	4.478	1.000	-7.01	14.94
	No system	2.78	4.478	1.000	-8.20	13.75
No system	ACE	1.19	4.478	1.000	-9.79	12.16
	Sliding carpet	-2.78	4.478	1.000	-13.75	8.20

Based on observed means.

No Between-Subject, Fixed or Random Effects Across the Data Sets

Conduct of the ANOVA and mixed model analyses across the four measures L4L5 Disc Compression, L5S1 Disc Compression, Baggage Handler Reach and Baggage Handler Trunk Rotation Tests permitted tests for between-subject effects as described in Chapter 2. In addition, the mixed model analysis permitted tests for fixed and random effects across all four measures for the baggage compartment configurations (*ACE, Sliding Carpet* and “No

System”), bag position (Left, centre, right) and the across the combined configuration and position data.

The between-subjects tests showed that there were no significant effects and the mixed model analyses, using Type III tests of fixed effects, found no fixed effects regardless of whether L4L5 Disc Compression, L5S1 Disc Compression, Baggage Handler Reach or Baggage Handler Trunk Rotation was selected as the dependent variable.

Data Set 2: The Ergonomists Opinions

The twenty Certified Practicing Ergonomists (CPE) that participated in this study were asked to view the twenty-seven MPEG video files and make a judgement on which row of each MPEG did the baggage handler exhibit the posture with the highest risk of a back injury, and which posture exhibited the lowest risk of a back injury. Accordingly, each CPE subject made fifty-four decisions, twenty-seven highest and twenty-seven lowest injury risk judgements between the postures exhibited by the nine baggage handlers across the three mock-up configurations.

The CPE response data sorted “Highest Risk of Back Injury” are at Appendix No. 26 and the data sorted “Lowest Risk of Back Injury” are at Appendix No. 27.

As described in Chapter 2, the ergonomists responses were converted into ratings to permit comparison between the *ACE*, *Sliding Carpet* and “No-system” mock-up configurations.

The means and standard errors returned by the two tailed covariate analysis for the three mock-up configurations *Ace*, *Sliding Carpet* and “No System” using the ergonomists opinion rating data are shown in Table 3.25 and presented graphically in Figure 3.5. The ergonomists opinion data returned a marked difference between *ACE* and *Sliding Carpet* configurations and between the *ACE* and “No-system” mock-up configurations. There was also a noticeable difference in these data between *Sliding Carpet* and “No-system”.

Table 3.25
Ergonomists Opinion Rating Data

Estimates[a]

SYSTEM	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
ACE	25.067	.497	57.001	24.071	26.062
Sliding carpet	15.467	.497	57.001	14.471	16.462
No system	13.400	.497	57.001	12.405	14.395

a. Dependent Variable: RATING.

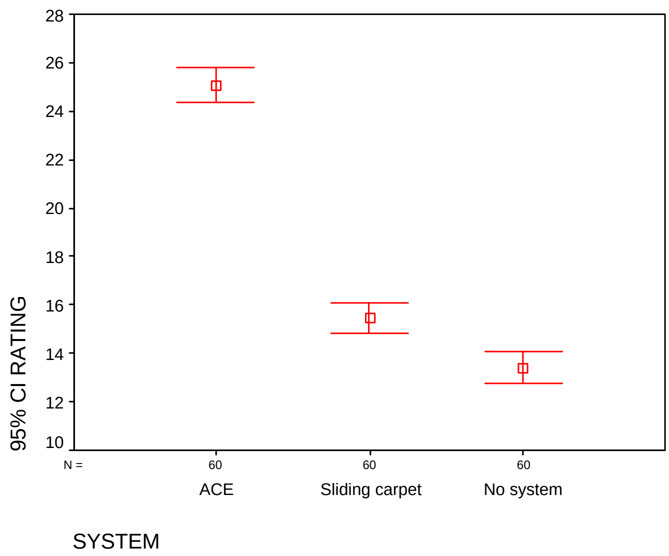

Figure 3.5
Comparison of Ergonomist Opinion Ratings for Baggage Compartment Configurations *ACE*, *Sliding Carpet* and "No System"
(Rating Score)

Analysis of Variance Tests Across all the Ergonomist Opinion Rating Data

Table 3.26 shows the results of the two-tailed multivariate mixed model analysis of variance that was conducted using the ergonomists opinion data (see Appendix 28) for the three aircraft mock-up configurations *ACE, Sliding Carpet* and "No System". The test confirmed the differences observed in the data between the three mock-up configurations were significant at the 95% (.005) confidence level. That is, the test confirmed the *ACE* result was significantly different to that for *Sliding Carpet* and "No System" and that also

Sliding Carpet was significantly different to “No System”, based on the ergonomists opinion rating data.

Table 3.26
Mixed Model Analysis of Variance:
Ergonomists Opinion Ratings for Baggage Compartment Configurations *ACE*, *Sliding Carpet* and “No System”
(Rating Score)

Pairwise Comparisons[b]

(I) SYSTEM	(J) SYSTEM	Mean Difference (I-J)	Std. Error	df	Sig.[a]	95% Confidence Interval for Difference[a]	
						Lower Bound	Upper Bound
ACE	Sliding carpet	9.600*	.703	57.001	.000	7.866	11.334
	No system	11.667*	.703	57.001	.000	9.933	13.401
Sliding carpet	ACE	-9.600*	.703	57.001	.000	-11.334	-7.866
	No system	2.067*	.703	57.001	.014	.333	3.801
No system	ACE	-11.667*	.703	57.001	.000	-13.401	-9.933
	Sliding carpet	-2.067*	.703	57.001	.014	-3.801	-.333

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Adjustment for multiple comparisons: Bonferroni.

b. Dependent Variable: RATING.

It is of interest that the results of the analysis of variance adjusted for both baggage compartment configuration (*ACE*, *Sliding Carpet* and “No System”) and bag position (Left, Centre and Right) depicted in Figure 3.6, shows that the statistically significant differences, at the 95% confidence level, between the *Sliding Carpet* and “No System” ergonomists opinion data related to the centre bag position data and the right bag position data, as Figure 3.6 shows. The results show there was little or no difference between the *Sliding Carpet* and “No System” data for the left bag position.

This test result indicates that baggage handler postures represent a significantly higher back injury risk when stacking baggage to the right and centre bag positions of *Sliding Carpet* than when stacking into the same positions when no system is fitted to the aircraft. It was likely the baggage handler postures are influenced adversely by the aircraft door that further restricts the baggage handler work space when stacking into centre and right bag positions.

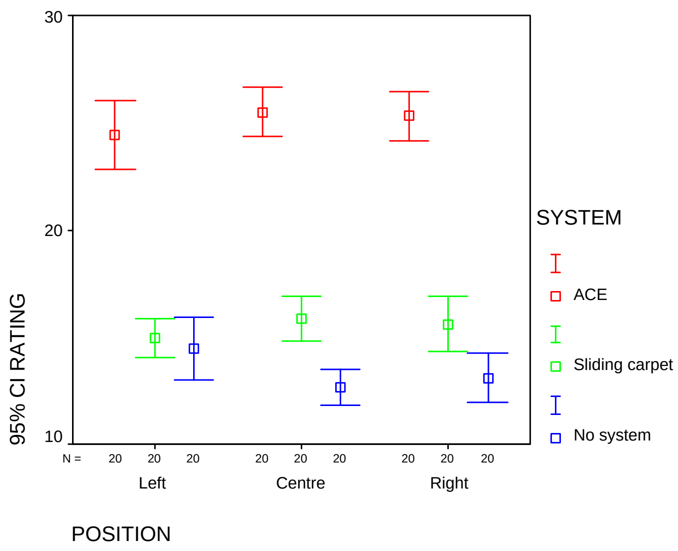

Figure 3.6
Comparison of ergonomist opinion ratings adjusted for baggage compartment configuration and bag position
(Rating Score)

No Between-Subject Effects or Fixed Effects Across the Data Sets

Conduct of the analysis of variance tests and mixed model analyses of the ergonomists opinion ratings permitted tests for between-subject effects. In addition, Mixed Model Analyses permitted tests for fixed and random effects across all ergonomists opinion ratings. These tests showed that there were no significant effects and the mixed model analyses found no fixed or random effects.

Statistical Corroboration

Appendix 29 details the outcomes of the additional statistical tests conducted to corroborate the results reported here for the ANOVA, MANOVA and mixed model analyses.

All the tests on the L4L5 disc compression data, the L5S1 disc compression data, the reach data, the trunk rotation data and the ergonomists opinion data returned results which aligned directly with the results of the multivariate tests reported here. Accordingly, it is most unlikely that any errors due to the assumptions and methods of the various tests have impacted on the outcomes of the analyses.

Summary of the Findings from the Phase 4 Laboratory Trials

In the biomechanical data set, three of the four measures gave consistent results. The ANOVA and mixed model analyses tests returned that loading baggage into the *ACE* mock-up configuration represented a higher risk of injury, due to statistically significantly higher disc compression loads on the L4L5 and L5S1 discs in the lower back than when loading *Sliding Carpet* or “No System” and that baggage handlers had to reach statistically significantly further when stacking baggage into *ACE* than when loading *Sliding Carpet* or “No System”.

The only measure which did not return a difference between the *ACE* configuration and the others was the trunk rotation measure.

None of the four measures L4L5 disc compression, L5S1 disc compression, reach or trunk rotation returned any difference between the Sliding Carpet and “No System” baggage compartment configurations.

The ergonomists opinion rating data set returned similar results in relation to the *ACE* aircraft baggage compartment configuration. The MANOVA and covariate tests showed the ergonomists opinion ratings indicated the *ACE* configuration to be a higher back injury risk statistically significantly more often than both the other mock-up configurations. However, the ergonomists opinion data also returned a higher back injury risk for *Sliding Carpet* significantly more often than for “No System”.

Further analysis revealed that this unexpected outcome was due to ergonomists opinion that postures adopted when loading baggage into the centre and right baggage positions of *Sliding Carpet* were a higher risk of back injury statistically significantly more often than the other systems. Further analysis of this unexpected outcome can be found in the Chapter 4 Discussion.

The additional statistical tests conducted to back up the ANOVA, MANOVA and mixed model analyses, returned outcomes which corroborated the test results.

3.5 PHASE 5: RISK ASSESSMENT OF THE PROTOTYPE RTT LONGREACH LOADER

Appendix No. 30 contains the risk assessment outcomes from the assessment of the manual handling risks associated with loading a B737 aircraft baggage compartment using the prototype Telair RTT Longreach Loader (RTT).

To provide a benchmark, the risk assessment team first assessed the loading of an aircraft without using the RTT Loader (see Hazard No. 1, Appendix No.30, p1). The hazard previously identified in this study as a major back injury problem, by the airline safety managers in Phase 2 and by the baggage handlers in Phase 3, the lifting and stacking of baggage into the baggage compartment of narrow-body aircraft, was assessed as an extreme risk by the assessment team. The group considered that a permanent injury was possible despite a number of hazard control strategies having been in place across the industry, they were the manual handling lifting training and physical fitness training provided to baggage handlers, the 32kg baggage weight limit, a 50kg cargo weight limit unique to Qantas and a team lift procedure for items over 32kg.

However, it is clear, based on the literature and the findings of biomechanical modelling in Phase 4 of this study, that these administrative controls were unlikely to be effective given the significant musculoskeletal loads experienced by baggage handlers. Notwithstanding, the risk assessment team felt there were a number of problems with the industry's application of these interventions, as Appendix 30 shows, making the likelihood of successful mitigation very remote. For instance, there was consensus of participants that not all airports provided any manual handling or physical fitness training for baggage handlers and not all airlines applied the weight limits on baggage and cargo. Furthermore, there was not always a second person available when a team lift was required to handle an item of baggage or cargo over

32kg. Such anomalies are consistent with the principles of the hierarchy of hazard control described previously and underpin the reasoning behind the concept that administrative controls, such as these are not as effective as engineering or other higher order hazard controls.

The use of the RTT loader to position the baggage and cargo to the height and location required within the baggage compartment was considered to result in a significant reduction in manual handling load on baggage handlers. The team assessed the risk of a manual handling injury while using the RTT loader as a moderate risk with the likelihood of a serious injury reduced to a rare occurrence.

It was found that the RTT Loader eliminated the need for baggage handlers to lift baggage and cargo. High risk lifting and twisting postures observed in baggage handlers stacking baggage in narrow-body without using an RTT Loader, and seen in the earlier phases of this study, were significantly reduced by use of the RTT loader. Figure No 3.7 shows one of the risk assessment participants using the RTT Loader to position baggage at the height and position needed within the aircraft compartment,

The principal manual task using RTT changed to one of pushing baggage off the roller head of the RTT loader with the baggage already at the height needed (see Figure 3.8). However, kneeling postures similar to those observed in other narrow-body stacking activities without use of the RTT, were still required, albeit without the need to lift baggage from the floor level.

Figure 3.7
Using the Prototype RTT Loader
to Position Baggage Within a Sliding Carpet Equipped
B737 Baggage Compartment

The consensus view of participants was that to gain the benefits of the RTT, it had to be used in conjunction with a *Sliding Carpet* system fitted to the aircraft baggage compartment. Otherwise, the benefits were negated by the need to lift baggage off the RTT to shift it from the aircraft doorway into the interior of the baggage compartment.

Other baggage and cargo handling issues were raised by the participants in the risk assessment. The impact of not correctly positioning the RTT was considered to be a potentially significant risk multiplier. If the RTT was not positioned correctly for each item of baggage or cargo, lifting baggage was still a frequent need and the risk associated with those lifts were potentially significant, especially if the RTT itself became an obstacle around which the item had to be lifted or stacked.

The issue of baggage handlers using RTT having to operate and position the unit with their non-dominant arm/hand while guiding baggage into position with their dominant hand/arm was considered a possible source of injury risk.

Also, small and light items did not transit the gradient of the RTT Loader when positioned high under the roof of the baggage compartment. A redesign was needed to reduce the angle of the initial belt section of RTT to minimise the gradient.

Figure 3.8
Using the Prototype RTT Loader
to position baggage at the correct height without lifting

Furthermore, RTT could not be used for all large items, such as the largest dog containers, since RTT took up a significant amount of space in the aircraft doorway, as Figures 3.7 and 3.8 shows, and the largest containers would not fit through the opening.

As Appendix No. 30 shows, the participants also identified a number of other issues with the prototype RTT design, such as control sensitivity, which the designers would have to address in the production models.

Baggage handlers observed using the RTT Longreach Loader appeared to quickly adapt to stacking and unstacking baggage with the loader, despite only rudimentary training being provided. All participants reported that they felt less than two aircraft loading sequences were required to become proficient enough to make a major reduction in lifting and twisting while working in the baggage compartment of narrow-body aircraft. Once personnel became familiar with positioning the RTT for each individual bag, the manual workload diminished remarkably.

It was apparent that the RTT Longreach Loader significantly reduced the manual handling load of baggage handlers stacking baggage into Sliding Carpet. The need to lift baggage from the aircraft floor to stack above shoulder height was effectively eliminated. Albeit, kneeling postures, pushing, pulling and some lifting of baggage were still a feature of the work

CHAPTER FOUR:
DISCUSSION

The intent of the early phases of this study was to confirm the magnitude of the baggage handler injury problem, explore the related state of knowledge within the airline industry and investigate opinions of key stakeholders such as the aircraft and equipment manufacturers, airline safety professionals and baggage handlers concerning causation and prevention. It was not to attempt comparisons of those opinions and knowledge between airlines, between safety professionals or between baggage handlers of different nationalities. The two final phases of the study were designed to investigate the injury prevention benefit, or otherwise, of two narrow-body aircraft in-plane baggage systems, *ACE* and *Sliding Carpet*, and that of a prototype mechanical loader, the RTT Longreach Loader.

4.1 DISCUSSION OF RESULTS

The Aircraft Manufacturers

Although it was apparent that the aircraft designers had not previously been made aware of the problem of injuries to airline baggage handlers and their costs to the industry, to the airlines and to the baggage handlers themselves, the designers initial response seems to have been one of denial. *Edwards (1997)* suggested that "*Denial – refusal to acknowledge the obvious – preference for self justifying fantasy*" was a pathogen, a danger factor, which allowed individuals to "*gloss over*" evidence of a problem with potential disastrous effects on safe operations. Clearly, the same can be said of designers who fail to acknowledge that high incident rates are a direct result of inadequate design hazard control where high residual risks having been transferred to the end users of their designs. This seems to have been the case with some aircraft baggage compartment designs. Certainly, several of the aircraft interiors designers involved in Phase 1 of this research project, did not want to acknowledge any ownership of the problem in their aircraft designs.

In this and several earlier studies, the failure to provide safe baggage systems has been highlighted, especially in narrow-body aircraft baggage compartments which transfer unsatisfactorily high manual handling risks to end users.

Since the genesis of this research project, some of the major aircraft manufacturers have participated in this and other studies and the literature condemning traditional baggage handling systems and methods has been growing. For example, *Tapley and Riley (2005*) recently condemned the industry's performance in this area:

"Research indicates that the manual loading and unloading of baggage onto narrow-bodied aircraft has been identified as a high risk operation for more than 20 years".

Yet new narrow-body aircraft continue to be delivered every day without any attempt to address the baggage handler injury issue. Baggage systems in those aircraft are still just an empty space in which some-one must stack the passengers' baggage.

Some of the manufacturers have taken the view that aircraft designs would change only when there was industry consensus on the need, as *Briggs (1997)* forewarned:

"*there will have to be airline industry consensus before the aircraft manufacturers will carry out design changes to their aircraft*".

However, industry consensus may be very difficult to achieve.

Like many safety solutions, baggage handler injury prevention at design stage comes with a significant upfront cost, while the downstream costs of not intervening at the design stage may not have been clearly understood in the past.

This circumstance must change and the emerging evidence of high costs of baggage handler injuries should be included in aircraft life cycle cost analyses. Then, any future recalcitrant designers will have more difficulty avoiding the matter.

None the less, like all business interventions, the business case for any proposed OHS solutions to this problem needs to demonstrate that the costs of development, installation and ongoing operation of the proposed interventions compare more than favourably against the projected ongoing cost of injuries (*Oxenburgh (1991)*). Without the cost data, the airlines and manufacturers will be unable to effectively make a case for change in this area. There is also a role for the workers compensation fund managers to ensure the costs of baggage handling injuries are made prominent, although there will probably be a need for improvements in claims reporting and data coding in many jurisdictions before the true costs will emerge.

An issue clearly exacerbating the problem of finding effective solutions to the baggage handler injury problem in the past has been the financial viability of commercial transport aircraft, which effectively rests with their ability to uplift payload and operate over long distances. All manufacturers strive to improve their aircraft designs to increase their payload and range capabilities. This is usually achieved by maximising the benefits of available technology and minimising the weight of the aircraft structure itself, leaving the greatest possible margins for payload and range, thereby maximising the economic capability of the designs.

Certainly the traditional narrow-body aircraft baggage compartment designs, which amount to nothing more than empty spaces, admirably meet those traditional aircraft performance criteria. The empty spaces and their surrounding fibreglass compartment structure weigh very little, and have very little impact on payload or range capability.

The aircraft performance engineers jealously guard their aircraft designs against unnecessary or non-productive weight. The payload/range equation will always be a major issue in the competitive high stakes new aircraft market (see for example *Norman (2000)*). The airlines will always select aircraft which will carry the largest payload over the longest range so they will maximise yield on any route in any market.

However, the available payload and range of modern transport aircraft have been significantly improved over older generation aircraft, due largely to the advent of much higher power engines and new synthetic materials that are stronger and significantly lighter than the metals utilised in first generation jet aircraft. These aircraft performance advances have allowed many other improvements in design, especially in the area of passenger service, comfort and entertainment. There is surely room also for improvements in baggage handler injury causation.

To make matters worse, many airlines are consistently not profitable (see *Walker (2001*) and *Flint and Farrar (2004)*), and the costs of baggage handler injuries may be a very small proportion of their total operating costs. However, the costs of baggage handler injuries should be factored into the aircraft purchasing decisions. With airline profit margins, even in the profitable airlines, as low as 4% (see *McClure (2004)* and *Biz/ed (2005)*), the differential cost of potential injuries associated with any aircraft designs could sway the decision between two otherwise equivalent aircraft types.

Never the less, industry agreement on any proposed solution to the manual handling problem in the aircraft baggage compartments may only be achieved provided the aforementioned aircraft performance precepts are not significantly or unduly degraded. To gain universal acceptance by the industry, any engineering solution will have to take these performance issues into account and not add significant structural weight to the aircraft. Otherwise, the cost impacts to the ongoing aircraft operation may outweigh the ongoing costs of the injuries presently being experienced by the airlines.

Airbus Industries seem to have understood this argument, since all their aircraft, including their Airbus A320 narrow body aircraft, are available with mechanised loading systems (see Figure 4.1) and the design has eliminated entirely the high risk tasks associated with the manual stacking of baggage and cargo inside those baggage compartment.

Airbus has effectively applied the traditional wide-body aircraft solution to narrow body aircraft. However, at the time of the Phase 1 meetings in this study, Airbus indicated that only 60% of their customer airlines had purchased aircraft with the mechanical loading system fitted. The others had taken the bulk loading option (see for example Figure 4.2), and required their baggage handlers to manually stack baggage and cargo inside the aircraft baggage compartments.

Figure 4.1[38]
Loading palletised freight into an A320 aircraft

In addition, Airbus also make both *ACE* and *Sliding Carpet* installations available to customers who do not wish to take the mechanised system option:"…*Full provisions can be provided for the installation of the Sliding Carpet System (supplied by Scandinavian Belly Loading Co. AB) and for the ACE Telescopic (supplied by Air Cargo Equipment Corp.) These systems can be installed in both forward and aft fuselage and mean that baggage can be loaded by one person inside the aircraft."* (*Airbus (2005)*).

[38] Photo courtesy of Airbus, http://www.airbus.com/en/aircraftfamilies/a320/freight.html

Figure 4.2[39]
An A320 aircraft in Bulk Load Configuration

The Airline Safety Managers and Baggage Handlers

At the beginning of this research project in the mid 1990’s, only one previous study was available, that by *Lundgren et al (1988)* which looked at just one airline’s baggage handler injury costs at a single Scandinavian airport, concerning the magnitude of the problem of injuries to airline baggage handlers. There was no previous literature identifying the costs of airline back injuries as a subset. Phase 2 of this project established beyond doubt that there were significant ongoing costs associated with these injuries.

The cost and injury frequency data included in Table 3.2 was the first published information on the costs of airline baggage handler back injuries across a reasonable sample of the global industry. This study showed the costs compensation, medical expenses and rehabilitation in 16 major airlines to be US$17.6m, US$23.6m, US$21.7m in the three years 1992 to 1994. *Culvenor (2004)* reported that Qantas alone had baggage handler back injury costs, for compensation alone, of over US$10m (A$14.1m) over 6 years '97 to '03. On average this would account for around US$5m in a 3 year period, around 30% of the total for sixteen major airlines just five years earlier.

Clearly, the costs associated with baggage handler injuries have been escalating.

The Lost Time Injury Frequency Rates (LTIFR) calculated from data captured in this study returned rates forty times worse than best practice as it was at that time. World's best practice organisations, for example Du Pont *(Brock 1996)* and ICI Australia *(ICI Australia 1996)* consistently experienced LTIFRs below 1.0. This project found that injury frequency rates amongst the baggage handlers were consistently above 40.

Without the need for any further research, these consistently high incident rates should have been evidence enough that the traditional methods of prevention were inadequate.

More recently, others have published corroborative information about the magnitude and cost of baggage handlers injuries (see for example *Korkmaz et al (2006)*, *Tapley and Riley (2005),* and *OAIEA (2004)*).

In this study, there was considerable consensus between the safety managers and the baggage handlers on a range of issues surrounding the causes and prevention of back injuries in the baggage handler workforce, as Table 4.1 shows. Narrow-body aircraft baggage compartments were considered by both groups to be the highest risk working environment and stacking of baggage in narrow-body aircraft was the task considered to be highest risk of back injury most often by both safety managers and baggage handlers alike.

Pushing baggage from the doorway into the interior of the aircraft baggage compartment, the task that is entirely eliminated by installing and using in-plane narrow-body baggage systems such as *ACE* and *Sliding Carpet*, was the task considered highest risk second most often by both safety managers and baggage handlers.

The contrast in opinion between the two groups concerning the importance of equipment maintenance is also of interest. Significantly more baggage

[39] Photo courtesy of copyright owner Chris Sheldon, http://www.airliners.net/open.file/063493/M/

handlers (121: 78%) rated equipment and aircraft maintenance a potential solution than did the safety managers (2: 13%) in this study. No doubt, the baggage handlers confront first hand the issue of poor equipment maintenance with the need for additional heavy manual handling work, as described in Chapter 1. It's not surprising that baggage handlers would want a solution but the reason the safety managers would rate the issue below other administrative solutions needs further investigation. However, to do so was not within the scope of this study.

All the safety managers and three quarters of the baggage handlers in this study agreed that heavy baggage was a significant concern and a limit needed to be set. The recent action by a number of airports to introduce a 32kg maximum limit on passenger baggage, reported in Chapter 1, would suggest there were many in the industry who agreed. For example, *Tapley and Riley (2005)*, in their analysis of musculoskeletal disorder data for baggage handlers in the UK, gave reserved support to the introduction of the 32kg limit by the industry:

" *The aviation industry, however, has recently adopted a voluntary 32kg single bag weight limit, which appears, according to industry figures to be reducing the numbers of reported incidents*"

Figure 4.1
Consensus of Solutions:
Safety Managers and Baggage Handlers

Solution	Airline Safety Managers n=16	Baggage Handlers n=156
Limit baggage weight and size	16	114
Provide mechanical assistance devices	14	93
Better training of baggage handlers	14	138
Introduce In-plane Stacking systems	9	122
Re-design baggage systems to account for ergonomic risk	9	111
Fitness and warm up programs	8	98
Better rostering and job rotation	3	119
Improved equipment maintenance	2	121
Improved work rate and task control	2	104

However, as discussed in Chapter 1, to meet contemporary ergonomic guidelines the limit would need to be less than 10kg and it's doubtful that a 32kg limit will make a significant contribution. Indeed, some airlines who have participated in this study have had a 32kg limit in place for over 10 years and are still reporting significant injury rates amongst baggage handlers. *Culvenor (2004)* reported that for the six year period July 1997 to June 2003, Qantas Airways experienced 2916 baggage handler injuries that resulted in compensation claims at a cost of $A29.6 million. Of those 1,130 were back injuries that resulted in costs of $14.1 million. All Australian airlines, including Qantas, have had a 32kg baggage limit in place since 1993. While it could be argued that the 32kg limit may have stopped the injury rates climbing higher, the Qantas experience suggests it cannot be argued to be a realistic long term solution to the problem. Furthermore, in the biomechanical modelling that was carried out in this study a 32kg load on the hands was assumed for the purposes of calculating spinal load for each of the postures adopted by the subjects.

The greater majority of both groups also supported manual handling training as a potential solution to the back injury problem. Clearly, in most working environments, major changes to the workplace design precepts that were set by the system designers are often beyond the control of those managers and workers within that environment. Not surprisingly, workers look to solutions that are within their control and that promise improvements within the constraints set by the designers. Baggage handler manual handling training clearly falls into that category. However, many airlines have for many years had baggage handler training programs in place, as reported in this study, yet the injuries are continuing unabated, as the recent authors have shown (see *Tapley and Riley (2005), OAIEA (2004), Culvenor (2004)* and *Korkmaz (2006)*). Further, the biomechanical manual handling loads associated with baggage handling, reported in this study, would cast doubt on the viability of training as a solution.

Effective long term intervention needs to address the baggage systems design, in particular, the design of the high risk workplaces. As *Hogwood (1996)* concluded:

"*The narrow-body aircraft hold has been correctly identified as an ergonomic disaster……it is up to the user group to apply pressure to the manufacturers of in-hold systems for their products to be viable options*".

Prophetic words but now ten years on and nothing much seems to have changed, Hogwood's user group, the airlines and the baggage handlers, still seem to be without an effective solution across the industry, despite a considerable body of evidence that stacking baggage in the restricted confines of narrow body aircraft baggage compartments generates such high musculoskeletal loads, especially in the low back, that traditional low order administrative interventions such as training and the conservative 32kg weight limit, are not effective enough to markedly reduce the injury rates.

Although the twenty ergonomists surveyed in Phase 4 of this study were not asked for an opinion on their perceptions of the overall risk of injury to baggage handlers based on the postures they observed in the MPEG video analyses, all informally commented on the extreme nature of the manual handling work and the high risk postures adopted by the trial subjects. It seems the airline safety managers and baggage handlers themselves also recognised this when rating the work in the baggage compartments the highest risk working environment and stacking baggage the highest risk task.

Design solutions to reduce the residual risk to baggage handlers clearly need to be found. The evidence for the need is now overwhelming. All previous authors, the baggage handlers, airline safety professionals, and specialist ergonomists have all agreed about the high risks involved in the work.

However, a major question remained to be answered: "*Are the existing in-plane stacking system designs the answer?*" Phase 3 of this study provided an answer, in part, to that question.

Analysis of ACE and Sliding Carpet

Phase 3 of this research project measured the comparative benefits of the two commercially available narrow-body in-plane stacking systems *ACE* and *Sliding Carpet*. The study also compared the ergonomic benefits of both systems against loading narrow body aircraft baggage compartments without either system installed.

Due to the significance of the possible outcomes and their potential effect on the industry, multiple measures were undertaken. To establish any biomechanical load differential between the baggage compartment configurations, computer modelling of postures adopted by baggage handler subjects was carried out using each of the two systems' configurations and a "no system" configuration. First principles measures of the baggage handler subjects' differential reach and trunk rotations were completed, modelling using a contemporary biomechanical modelling program was carried out and finally the opinions were obtained of ergonomic experts on the differential risk of the various postures resulting from stacking baggage in the three aircraft compartment configurations.

Evidence of Differences in Risk of Back Injury Risk between ACE, Sliding Carpet and "No System"

There was a high level of consistency between the three biomechanical measures of differential back injury risk between the three aircraft baggage compartment configurations: *ACE*, *Sliding Carpet* and "No System"

All three measures found there were significant differences, as follows:

Between *ACE* and *Sliding Carpet*:

The biomechanical modelling of postures returned statistically significantly higher disk compression forces generated in the lower back when loading *ACE*.

Also, the direct measures of reach distances exhibited by the subjects showed that when stacking baggage in *ACE*, the subjects reached statistically significantly further than in *Sliding Carpet*.

Furthermore, a statistically significantly greater number of ergonomics experts considered the postures exhibited by baggage handlers using *ACE* were a higher risk of back injury than those exhibited in *Sliding Carpet*.

Clearly, the results of this study showed that there was a significantly different higher risk of low back injury when stacking baggage into an aircraft fitted with *ACE* than with *Sliding Carpet*.

Between *ACE* and "No System":

The biomechanical modelling of postures showed statistically significantly higher disk compression forces generated in the lower back when loading *ACE*.

Similarly, the direct measures of reach distances exhibited by the subjects showed that when stacking baggage in *ACE* , the subjects reached statistically significantly further than when no system fitted to the aircraft was simulated (i.e. the "No System" configuration).

In addition, a statistically significantly greater number of ergonomics experts considered the postures exhibited by baggage handlers using *ACE* were a higher risk of back injury than those exhibited when no system fitted to the aircraft was simulated (i.e. the "No System" configuration).

Between *Sliding Carpet* and "No System":

The results of comparison between *Sliding Carpet* and "No system" showed that the biomechanical modelling of postures showed disk compression forces generated in the lower back when loading *Sliding Carpet* and "No system", although both relatively high, were not statistically significantly different.

Similarly, the direct measures of reach distances exhibited by the subjects showed that there was no statistically significant difference in the distances reached by subjects when stacking baggage in Sliding Carpet against when no system fitted to the aircraft was simulated (i.e. the “No System” configuration).

However, in stark contrast, a statistically significant greater number of ergonomics experts considered the postures exhibited by baggage handlers when stacking baggage when no system was fitted to the aircraft (i.e. the “No System” configuration), were a lower risk of back injury than those exhibited when *Sliding Carpet* was simulated.

Further analysis was carried out to try to explain this outcome. The experimental design had controlled for all known potential confounding variables and the dependent variable of each trial was the configuration of the mock-up. Between *Sliding Carpet* and “No system” the only changes in the mock-up configuration were the floor step insert and the aircraft door that were both in place for the ACE and *Sliding Carpet* trials but were taken out for the “No system” trials.

The data captured in the trials was not able to be sorted with the step in the floor as the sole dependent variable, so its influence could not be isolated. However, the data was sorted to provide a measure of the influence of the aircraft door as the dependent variable.

It was felt the door would probably have influenced baggage handler posture when bags were stacked towards the door which in this study design, were bags stacked in the centre of the aircraft mock-up and to the right side of the aircraft mock-up.

Figure 4.3 shows a baggage handler from these trials stacking baggage into the right hand position. In the figure, *ACE* is the top row, *Sliding Carpet* is the centre row and “No System” is the bottom row.

The top centre and middle images clearly show the aircraft door protruding into the workspace and the baggage handler having to adjust his posture to get the bag in behind the door. This has resulted in the baggage handler leaning further over in the top row (*ACE*) and centre row (*Sliding Carpet*) images. In the bottom row (“No System”), the baggage handler has a much more upright posture than either of the other two, *ACE* or *Sliding Carpet*.

Figure 4.3
A baggage handler loading baggage into the top right hand position
Ace (top), Sliding Carpet (centre) and “No System” (bottom)

Statistical tests, described in Chapter 3, were then undertaken to ascertain if this difference was statistically significant across the trial population.

All the statistical tests showed there was a statistically significant greater number of ergonomist opinions that baggage handlers loading baggage into the centre and right bag positions had a lower risk of back injury when loading into a baggage compartment without a system fitted (“no system”) than when loading into “Sliding Carpet”.

Clearly, the position of inward opening aircraft baggage compartment doors adversely affected the postures of the trial subjects and increased the back injury risk of baggage handlers working with *ACE* and *Sliding Carpet*. This has relevance for the Boeing B737 and B717 aircraft as well as the Douglas DC9 and MD80 series aircraft fitted with *ACE* or *Sliding Carpet*.

Validation Activities

To provide a benchmark for comparison purposes and ensure that the mock-up trials at University of Ballarat were as realistic as possible, baggage handlers at SAS in Stockholm and Copenhagen , United Airlines in San Francisco and Qantas Airways in Melbourne were videotaped while loading narrow-body aircraft. In Stockholm and Copenhagen, video footage was taken of loading of some MD80 narrow-body aircraft with *Sliding Carpet* fitted and some without any system installed in the baggage compartments. In San Francisco footage was taken of loading of an Airbus A320 narrow-body aircraft fitted with *Sliding Carpet*, several B727 narrow-body aircraft fitted with *ACE* and several B727 aircraft without a system fitted. In Melbourne, video footage was taken of baggage handlers stacking baggage into Qantas and Virgin Blue Airlines B737 aircraft fitted with Sliding Carpet and others without any system installed in the baggage compartments. Figures 4.4 to 4.9 show typical postures adopted by baggage handlers in the validation videos.

Figure 4.4 shows a baggage handler loading an ACE equipped Boeing B727 aircraft in San Francisco. The baggage handler was kneeling on the step presented by the floor sections of the ACE system bins, visible to the right of the baggage handler, then adopted a half crouch to reach the position the bag needed to be stacked.

Figure 4.5 shows the loading of an SAS MD80 aircraft at Stockholm. The aircraft was fitted with Sliding Carpet and the baggage handler was stacking a bag into the top right position behind the inward opening aircraft door protruding into the work space.

Figure 4.4
Baggage handler loading an ACE equipped Boeing B727 aircraft in San Francisco

Figure 4.5
Baggage handlers loading an MD80 aircraft fitted with Sliding Carpet in Stockholm

The additional head room of the Airbus A320 aircraft is obvious in the Figure 4.6 image of a baggage handler stacking freight into an ACE equipped A320 aircraft. The A320 has outward opening doors so they do not protrude into the work space.

Figure 4.7 shows a baggage handler stacking baggage into a Sliding Carpet equipped B737 aircraft in Melbourne. The inward opening door of the B737 aircraft clearly affected the posture of the baggage handler when stacking freight into the right hand side of the baggage compartment.

Figure 4.6
Baggage handlers loading an ACE equipped Airbus A320 aircraft in San Francisco

Figure 4.7
Baggage handlers loading a Sliding Carpet Equipped Boeing B737 aircraft in Melbourne

These validation activities confirmed that only one baggage handler was typically used to load each baggage compartment fitted with ACE or Sliding Carpet, where-as on every occasion baggage compartments were loaded without a system fitted, two baggage handlers were required. The second baggage handler had to shift the baggage into the interior of the baggage compartment to the person stacking the baggage inside, as Figure 4.8 shows.

Figures 4.9 shows that although the door aircraft does not encroach into the work space when working in the compartment interior, leaning postures were still adopted by baggage handlers carrying out the task.

Figure 4.8
Baggage handlers loading a Boeing B737 aircraft in Melbourne not fitted with a system. Note the second baggage handler required

Figure 4.9
A baggage handler in Melbourne loading a B737 aircraft not fitted with a system. Note: The second person was off-camera to the right

Apparent discrepancies between findings of this study and some earlier authors regarding trials of ACE & Sliding Carpet.

At first glance, the results of this Phase of the research stands against the findings of some earlier authors mentioned in Chapter 1. *Fokker (1986)*, *Jorgensen et al (1987)* and *Stokholm (1988)* each reported reductions in load on baggage handlers using narrow-body aircraft stacking systems.

Fokker (1986) claimed that "*the moving belt system substantially reduces the physical load of the baggage loaders*" and *"the workload reduction results from the deletion of the transportation and stowing in the compartment*". In fact, at the time of that prediction, the Sliding Carpet system was a prototype and had not been introduced to operations. Combination by *Fokker* of "*transportation*" in the compartment, with "*stowing*" in the compartment, confused the benefits of the system's elimination of the task of transferring baggage into the compartment interior and any benefit to the person stacking baggage in the system. In contrast, this study controlled for other variables and isolated the stacking task as the sole subject of review and the results here would indicate that the benefits mentioned by *Fokker* stem more from the elimination of the baggage transfer task, than from any significant improvement for the baggage handlers carrying out the stacking task.

Stokholm (1988) reported on the first trials of the Sliding Carpet system by SAS during October to December 1987. In that paper, the claim of reduced injury risks were based on a questionnaire given to baggage handlers containing "*questions regarding work load on joints and muscles*". The subjectivity of the baggage handlers responses reflected in the trial conclusions such as…."*Nearly 60% found that workloads on shoulders and elbows/wrists had been reduced to a greater or lesser extent*", and "*A majority (2/3) found that SLC was much better"*, suggests the study provided general guidance on the possible benefits of Sliding Carpet rather than any rigorous test and analysis.

The *Jorgensen et al (1987)* study was a trial of an *ACE* installation in an SAS DC-9 aircraft. Six subjects were measured working in the *ACE* fitted baggage compartment and then again in an equivalent compartment without a system fitted. Heart rate measures and electromyography (EMG) of four muscles, including the left and right erector spinae muscles of the back, were the principle measures. *Jorgensen et al* reported that the subjects were permitted to work at their own pace and useable EMG data was captured from only three subjects because of radio interference with the test equipment.

The reported outcomes were that the *ACE* system did reduce load on the back but only by a moderate amount. No statistical analysis of results was offered. Heart rate differential between using the system and not using the system was reported to be four beats per minute (bpm) on average during baggage stacking sequences. Larger differentials over 20bpm were reported during unloading sequences.

That study's reported conclusion of …"*14% reduction in duration of loading and unloading*" was also dubious since speed of work could easily be effected by the subjects' own outcomes expectations, and an ….*11% decrease in energy consumption by workers"* and …."*a marked decrease in postural muscle strain,* both were based on very small data sets and no statistical validation was offered.

Based on the reports, the experimental design of both these studies appeared to leave potentially conflicting variables uncontrolled and both based conclusions on very small data sets with no statistical analysis of measured differences between results with and without use of the *ACE* and *Sliding Carpet* systems

Possible Reasons That Trunk Rotation Measures In This Study Were Not Significantly Different

It was likely that trunk rotation when stacking baggage into the narrow-body aircraft baggage compartments was a function of fuselage width and bag position, as Figures 4 shows. Since, in these trials each bag was consistently placed in the same position to be retrieved by the trial subjects, to eliminate that potential confounding variable of reaching to different positions and any resultant variation effect on lifting postures, the need for the baggage handlers to rotate bags around their body into position for the *ACE* , *Sliding Carpet* and "No System" trials produced a symmetrical outcome where the measures would likely have counteracted one another across the data set, as Figure 4.10 shows.

Theoretically, for counter-clockwise rotations, as would be the case with a right-hand side entry door, as was simulated in these trials, around the body bag rotations would have been greater for the left bag position with *Sliding Carpet*, because the wall of the system was closer to the baggage handlers. However, the reverse would have been the case for the right bag position where the around the body rotation need would have been less for Sliding

Carpet than ACE, again because the wall was closer. Of course, the geometry would also reverse for left hand doors and clockwise rotations around the body as would be the case in Baggage Compartment 2, aft of the forward baggage compartment door. Also, the degree of rotation required for the centre bag position would have been the same regardless of the direction of rotation and baggage compartment configuration, as Figure 4.10 shows.

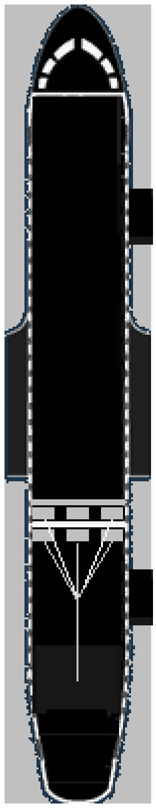

Figure 4.10
Comparative angles of rotation to stow baggage: Left, Centre. and Right bag positions

It was also apparent that the need to rotate bags around the body was the same when "No system" was simulated. Observation of baggage handlers showed that the second person consistently delivered each bag into the centre of the aircraft, so that in relation to the person stacking, there was virtually no difference whether the bags were delivered by a belt loader through a doorway in the side of the aircraft, as was the case with *ACE* and *Sliding Carpet*, or when delivered by a second person working behind the person stacking, as occurred when no system was fitted. Accordingly, the around the body bag rotation demand when no system was fitted was effectively the same as that of Sliding Carpet and the same counteracting geometry likely applied.

The trunk rotation outcomes may have been further affected by the varying degrees by which each subject moved their knees, as Figure 4.11 indicates.

Figure 4.11
A example of a baggage handler that shifted position of the knees for some lifts further than for others

In row A and row C, the baggage handler has shifted the knees to face the stack of bags, where-as in row B the rotation was half at the knees and half from the waist. Direct measurement of the angles of rotation between the hips and shoulders in this study did not identify a significant difference in this rotation between the three baggage compartment configurations.

Shifting of the knees was clearly a factor in risk control innately applied by the baggage handlers to varying degrees. It would have been taken up in the 3D biomechanical modelling and reflected in the resultant lower back disk compression measures.

Clearly, more study is required to fully understand the differential impact of trunk rotation of baggage handlers when stacking baggage into ACE, Sliding Carpet and when no baggage system is fitted.

Issues Regarding Application of the Michigan 3D Static Strength Prediction Model

There were two factors which had the potential to cause confounding errors on re-creation of baggage handler postures using the Michigan 3D Static Strength Prediction Program. The Program did not allow for kneeling postures at the feet. The Program assumed the feet were flat on the floor regardless of the angle between the foot and the lower leg. Also, it was not possible with the Michigan Program to change the distance apart of the feet or knees, as was evidenced by some of the postures adopted by the baggage handlers in this study.

However, since the Michigan Program was being used as a measure of postures between subjects loading baggage into the same positions “left”, “centre” and “right”, it was assumed any errors caused by these limitations were common across the matched sets of data and as such, did not adversely affect the comparison results. Also, the principle measures of interest using the Michigan Program were lower back disk compressions which were assumed to bear little relationship to any lower leg anomalies based on the algorithms reportedly used for the development of the model (see Michigan (1998)).

These anomalies with the Michigan Program had previously been reported and accepted by other researchers (see for example *Evans and Pratt (1994)*).

Work Heart Rate and Oxygen Consumption Measures Inconclusive

Work heart rate and oxygen consumption measures were attempted in this study but were found to be incompatible with the trial methodology.

Perusal of the graphs of these measures, detailed in Appendices Nos. 31 and 32 for heart rate and O_2 consumption respectively, shows that each trial sequence did not last long enough for the subjects' heart rates and O_2 consumptions to plateau. Across the entire sequence of subjects and trials, the values for both measures were still climbing when the subjects had filled the baggage compartment mock-up to the ceiling.

Clearly, for any differential in workload to be measured in future trials, subjects would be required to complete multiple stacks of baggage to the compartment ceiling so that the subjects' heart rates and O_2 measures plateau at the rates consistent with continued work in each configuration.

The Effect of the RTT Longreach Loader

Clearly, the long term solution to the ergonomic load on baggage handlers working in narrow-body aircraft has to be elimination of the need to apply high levels of biomechanical force while in the restricted kneeling postures made necessary by the limited ceiling height of the compartments.

While RTT Longreach Loader (RTT) does not fully eliminate the need for all manual work in the baggage compartment, it appears to make a remarkable difference to the ergonomic load on baggage handlers. Instead of having to lift bags from floor level up to ceiling height, the RTT was able to be positioned to deliver the bag at the height required. Accordingly, RTT seemed to significantly reduce the ergonomic demand for all lifts within the baggage compartment. The difference was most noticeable for the worst case lift, when lifting from below the waist, at floor level, to above head height when stacking in the top row. This was the task considered to be the highest back injury potential for baggage handlers, yet the RTT reduced the task to a simple push of the bag on the roller beds on the head of the unit, a relatively much lower risk activity.

The risk assessment team in Phase 5 of this study assessed the risk of stacking baggage in the narrow-body aircraft baggage compartments an "extreme" risk of manual handling injury. This outcome was consistent with the results of the biomechanical modelling of the baggage handler postures and the consensus of opinion of the ergonomists from Phase 4 and had been reported by many earlier authors such as ARTEX (1981), *Jorgensen et al (1987), Stokholm (1988) Hogwood (1996), McGill (2002) & Korkmaz et al (2006)*.

The assessment team consensus that the RTT loader significantly reduced the manual handling risk to baggage handlers has since been corroborated by another study of the RTT prototype. *Lusted (2003)* carried out an ergonomic assessment of thirty-two volunteer Qantas baggage handlers from eleven Australian capital city and regional airports. Lusted video-taped loading and unloading sequences and then used the Ovako Working-posture Analysis System (OWAS) (see *Karhu et al (1977)*) to classify the baggage handler postures when using RTT against loading using only a standard belt loader. Lusted trialled the RTT on a range of Qantas aircraft, but the OWAS results for the B737 analysis in that study were particularly pertinent here for comparison with the outcomes of this study.

Lusted (2003) measured noticeable reductions in manual handling risk when baggage handlers used RTT to load narrow-body B737 aircraft, Table 4.2 shows.

The outcomes from *Lusted (2003)* and the subjective risk assessment of the impact of the RTT prototype conducted in this study the system provided a positive injury prevention benefit and RTT seemed to be a "must have" piece of equipment for use in loading *ACE* and *Sliding Carpet*.

Access to the RTT loader in Phase 5 of this study was limited to a half day due to the limited time the prototype was available in Australia and competing access demands from other stakeholder groups. Accordingly, it was not possible to conduct more rigorous quantitative analyses. However, more rigorous research should be carried out to validate the outcomes of this study and accurately measure the differential biomechanical loading on baggage handlers using the RTT against not using the unit. The dynamics of the baggage loading environment are such that there are many potentially confounding variables which need to be carefully controlled in order to establish statistically significant causal links. For instance, the question of whether using RTT reduced baggage handler low back compression forces below the injury thresholds specified by *McGill (2002)* and *NIOSH (1981)* needs to be confirmed.

Table 4.2

OWAS Measures of the Benefits of RTT on B737 loading (from Lusted 2003)

Values in percent of use (%). Postures ranked in order of harm

Body Part	**Posture**	**RTT %**	**Belt loader %**	**Improvement**
Back	Straight	66	40	✓
	Bent	22	23	✓
	Twisted	5	7	✓
	bent and twisted	6	30	✓
Arms	2 below shoulder	92	83	✓
	1 above shoulder	5	12	✓
	2 above shoulder	3	5	✓
Legs	kneeling on one or both knees	100	100	
Neck	head free	78	43	✓
	bent forwards	11	27	✓
	bent to one side	3	0	✓
	bent back wards	4	0	✓
	Twisted	3	27	✓
Force being exerted (pushing pulling or lifting)	- equal to or under 10kgs	100	57	✓
	- between 10 and 20 kgs		32	✓
	- over 20kgs		10	✓

4.2 DISCUSSION OF OTHER BAGGAGE HANDLING INJURY PREVENTION ISSUES

OTHER DESIGN SOLUTIONS

The Sliding Carpet with Baskets

In 1993, Scandinavian Belly Loading AB developed a prototype basket system designed to operate with *Sliding Carpet* (*Scandinavian BellyLoading (1993)*). The system utilised fibreglass baskets that were loaded with baggage in the baggage room and then transferred to the aircraft for stowage in the aircraft using a belt loader and the *Sliding Carpet* (see Figure 4.12.

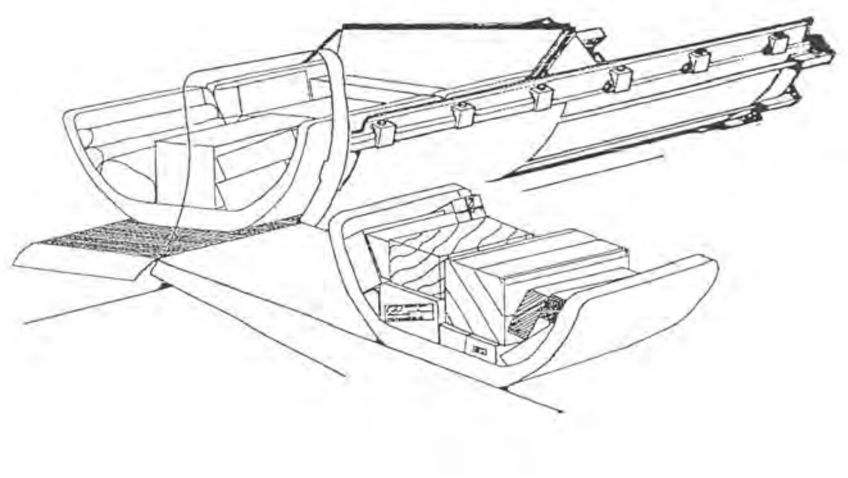

Figure 4.12[40]
The Scandinavian BellyLoading
Basket Version of the Sliding Carpet System

While the system did not progress to a production version, the concept was clearly ahead of its time. From a manual handling injury reduction viewpoint, the system had a combination of solutions that still have not been achieved by any other single system in airline operations today. All manual handling of baggage in the narrow-body aircraft baggage compartments was eliminated using the system, manual handling of bulk baggage outside the aircraft was eliminated and the baskets were open-topped which facilitated the use of mechanical lifting aids for loading baggage into the baskets inside the terminal. Truly, this was an attempt at a comprehensive engineering solution to the baggage handling injury problem.

Indeed, the containerised Airbus A320 is the only system presently available which offers this same opportunity for effective elimination of manual handling including the mechanical loading of containers in the baggage room (see Figure 4.13).

Figure 4.13[41]
The Airbus A320 Container with Door in Top of Container

These containers offer the first real opportunity for mechanical lifting aids similar to those used in other industries to be effectively utilised in airport baggage rooms (see Figures 4.14 and 4.15).

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[40] Diagram courtesy of Telair Scandinavian BellyLoading AB
[41] Photo courtesy of Air New Zealand (*ANZ (2005)*)

Figure 4.14
Ergobag[42]
Mechanical Lifting Aid Adaption for Airport Baggage Rooms

Figure 4.15
Trials of an Australian mechanical lifting aid by Qantas Airways

These lifting aids met with limited success and were not yet in widespread use due to the difficulty of accessing standard containers with solid tops. The lifting aid could not access the top of these containers making the stacking of baggage into the container awkward. Not withstanding some airlines are conducting trials of these systems (see *GHI (2000)* and *Cree (2003)*).

These solutions maybe more appropriate for open baggage barrows, but more design work was needed to improve the baggage grasping method of the units, an area that had been perceived as problematic in the past. (*Cree (2003)*)

RampSnake

RampSnake is another contemporary solution for loading baggage into aircraft yet to be investigated in the literature. Like RTT, RampSnake (see Figure 4.16) has been designed to eliminate the lifting task within the narrow body aircraft. RampSnake features a telescopic section which can curve and reach eight metres into the baggage compartments of the aircraft to position the bags at the ideal palcement and height required by the baggage handler. It is purported to be suitable for both narrow-body aircraft baggage compartments and wide-body aircraft bulk baggage holds alike. As with the RTT, the position and height of the RampSnake head is controlled by the loader working inside the aircraft.

The traditional high risk lifting task in the narrow-body aircraft would be eliminated by RampSnake and replaced with a comparatively lower risk pushing and guidance task similar to that of RTT.

RampSnake replaces the traditional belt loader currently in use by many airlines and is designed to be used with all aircraft, not only those fitted with ACE or Sliding Carpet systems as is the RTT, which the manufacturer promotes as an advantage. Interestingly, all of the systems weight stays on the ground, it is not part of the aircraft, a situation which will ensure the support of the aircraft performance engineers trying to maximise the aforementioned range and payload equation.

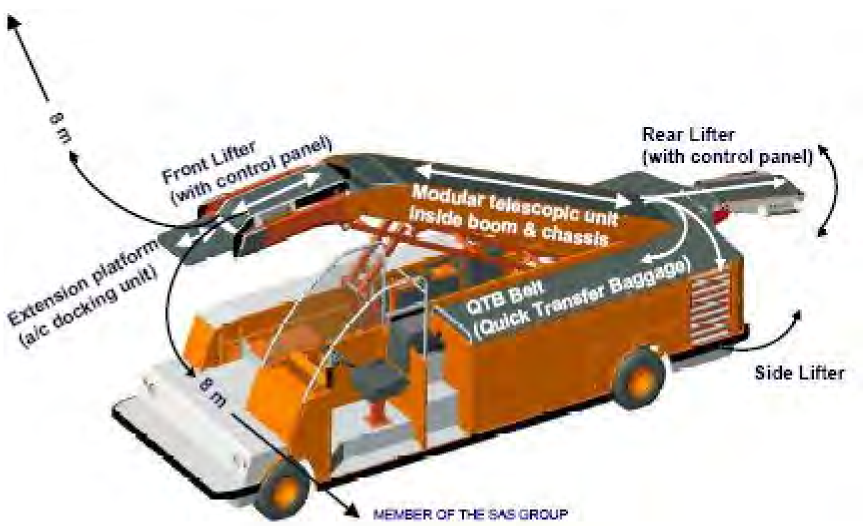

Figure 4.16[43]
RampSnake

[42] Photo Courtesy of Airport Ground Equipment AB, Ljungskile, Sweden
[43] Drawing courtesy of Paul Pieroff of RampSnake Inc (*Pieroff (2003)*)

While the true savings in reduced injury costs afforded by RampSnake are yet to emerge, the testimonials have been accumulating quickly, none better than that of the Executive VP of Arejdstilsynet (Danish Work Environment Service), H. Elo Petersen, who is reported to have said…. *"I have seen the RampSnake in operation at Copenhagen Airport – an amazing technical wonder, that eliminates the occupational lifting hazards when loading and offloading aircraft. Arbeidstilsynet (Danish OSHA) has for many years now been focused on this particular environmental occupational problem. With the introduction of RampSnake, this problem will soon be a thing of the past."* (cited in *Pierroff (2003)).*

Terminal design

Baggage sorting systems have been developed to meet the demands caused by the ever-increasing volume of passengers. Very high-technology solutions have been applied to ensure efficient sorting of baggage (see for example *Stearns (2005*)). Yet all the contemporary baggage systems have combined this state of the art technology with standards of ergonomics which have been ineffective for many years, as the example in Figure 4.17 shows.

The high technology ends at the baggage handler who the latest designs have continued to ignore. The lateral belt at the end of the systems has been designed to meet the needs of the average male. For example, the height of the baggage laterals and other carousels above the ground have been determined by using ergonomic scales that put the outcome near the median height for the standard male population. So the baggage system provides an adequate solution for baggage handlers around the median height, but the taller or shorter an individual is the less suitable is the solution. For very tall baggage handlers, as appears to be the case with the baggage handler in Figure 4.17, the belts have been far too low and resulted in stooping postures when lifting and increased the risks of injury significantly.

Figure 4.17[44]
Latest technology tilt tray baggage sorter

If the system designers persist with using a person to collect the baggage from the end of the baggage system and manually load baggage barrows and containers in the traditional way, then there will need to be a change in the design paradigm to permit the heights of baggage belts and carousels to be adjusted by each individual baggage handler to maximise their ergonomic advantage. No longer should baggage lateral belts and carousels be permitted to be set in concrete and only provide real ergonomic benefit to the middle 5% of the baggage handler population.

The Advent of Robotics Solutions

In applying contemporary hazard management theory to the baggage handling problem, elimination of the manual handling hazards would seem to be the ultimate aim. At the genesis of this research project, when robotics to eliminate manual handling was suggested as a potential long term aim for the industry (see Appendix No. 1, p5), the notion was viewed as fanciful at best, or more probably, foolish. In this study, baggage handlers supported mechanical assistance devices as a potential solution (see Table 3.9) up to a point. Clearly, there was concern about job security which also influenced their views.

[44] Photo courtesy of http://www.fkilogistex.com/airport/high-speed-sortation-systems/s-3000e-tilt-tray-sorter/

None the less, a small number of airlines, including Swissair and Qantas, have approached robotics manufacturers get them to look at applying robotics technology to the baggage handling problem. At the time there were three major stumbling blocks, the time taken for the robotics to sense each item of baggage and assess its characteristics, how the robot would grasp the baggage since baggage was a myriad of different weights and sizes and how to use the robotics intelligently to maximise space utilisation when stacking baggage.

However, these problems may have been solved. *Schnoor and Cottone (2003)* reported on the development of robotics technologies that utilise high speed computing to assess each piece of luggage, identify and determine precisely what type of baggage is being presented and the system calculates the best position in the container or on the barrow for each piece of baggage to be placed (see Figure 4.18).

Figure 4.18[45]
Grenzebach
Robotic baggage container loading for Airport Baggage Rooms

Koini (2004) reported on the positive outcomes of a 12 month operational field test of a robot in the baggage room at Zurich Airport. The robot operated around the clock seven days per week loading 30 to 45 items of baggage into each container. The report suggested the need for manual handling was reduced, particularly in relation to lifting heavy items which usually caused significant strain, and the numbers of injuries to personnel were also reduced.

[45] Photo Courtesy of Grenzebach Onero GmbH, Karksruhe

It will no doubt take some time for these robotics systems to be proven in normal airline operations and gain widespread industry acceptance. However, the Zurich experience suggests the day may be quickly approaching when the airport baggage room operation will be fully automated.

THE PIVOTAL ROLE OF THE OH&S REGULATORS

In the paper "*The Causes and Prevention of Baggage Handler Back Injuries: A survey of Airline Safety Professionals*" published as part of this research project in 1997 (see Appendix No. 20) that reported the outcomes of the Phase 2 survey, it was predicted that intervention of the OH&S regulators would probably be necessary to push the industry to accelerate development of effective intervention strategies. At that time, all except a handful of airlines had no limit set on the allowed weight of baggage and most relied almost solely on dubious administrative hazard control strategies such as job rotation, two person lifts and lifting technique training.

The industry cannot expect those soft interventions to deliver lasting results. Several authors have since reported on the outcomes of studies that have reviewed the weight of baggage lifted daily by airline baggage handlers. *Culvenor (2004)* reported that Qantas baggage handlers each lift an average of around 9 tonnes per work shift, *DWES (1999)* calculated that SAS baggage handlers at Copenhagen lifted an average of around 6 tonnes per work shift and this was reaffirmed again in 2005 by the Danish Trade Council (*DTC (2004*).

These figures are the reality the industry must address. The manual handling load on baggage handlers is so far beyond that which is acceptable or tolerable by human biomechanics, no amount of administrative control will be effective.

Several OH&S Regulators have begun ramping up action to force the industry to seriously address the baggage handler injury issue. At the fore was the Arbejdstilsynet, the Danish Work Environment Service (DWES). In 1998, the DWES inspected SAS baggage handling activities which resulted in some ground breaking directives being issued to SAS. After making an assessment of SAS baggage handling practices, DWES (*DWES (1999)* concluded that due to the weight and form of many of the items lifted, manual handling of baggage and cargo involved a ….”*substantial risk of physical injury*”. They also recognised that manual handling in aircraft cargo holds resulted in uncomfortable working positions and was an…*extremely high risk of physical injury*”, in both the short and long term,

DWES stressed also that manual handling activities airside, that is on aircraft movement areas on airports, such as the lifting, tossing and carrying baggage and cargo entailed a…..”substantial risk of physical injury”. The fast pace of the baggage handling work and the high individual daily weight amounts were also identified as negative factors that ….”elevate the risk level considerably”.

Interestingly, DWES indicated that the existing job rotation schemes did not reduce the loads sufficiently, further opinion that administrative controls were unlikely to be effective in this workplace and activity.

DWES criticised the airline for having not developed and implemented to an appropriate extent, suitable mechanical aids to help in carrying out the job tasks associated with baggage handling and they had not planned and organized the work in such a way that it could be performed in a sound manner from an OH&S perspective.

At the time, this was probably perceived as a harsh condemnation and singling out of SAS, who had possibly had done more than all the other airlines combined to that time, to try to address the baggage handler injury issues. They had been involved in early *Sliding Carpet* development, trials of the *Sliding Carpet* basket systems, trials of *Combi-Lifter* , a prototype baggage transporter, and probably the most foresighted of all, SAS developed and operational trialled telescopic baggage conveyors that went from the terminal baggage room all the way to the aircraft parking bays at one terminal at Stockholm Arlanda Airport. Another far reaching experiment that eliminated many of the baggage handling tasks but was not pursued.

The emerging literature appears to be proving DWES to have been correct in the general thrust of their action. In fact, many of the issues raised by DWES continue to apply to most, if not all airlines that daily expose the baggage handlers to significant manual handling injury risk.

The DWES pressure on SAS to eliminate the problem of manual handling in narrow-body aircraft clearly resulted in the development of RampSnake by SAS and probably also RTT by Scandinavian BellyLoading.

This was, as Executive VP of Arejdstilsynet (Danish Work Environment Service), H. Elo Petersen was reported to have said: "…*an example of how tough legislative demands to improve the working environment, can bring about innovative technical solutions"* (cited in *Pierroff (2003)).*

In 2003 in the USA, OSHA published its revised e-tool for Airline Baggage Handling which addressed a range of administrative controls for the recognised hazards associated with baggage handling activities (*OSHA (2003)*).

The e-tool provides some useful advice, as short term strategies, for people exposed to baggage handling risks with the equipment, systems and aircraft designs common today. For manual handling hazards on the aircraft parking apron, the e-tool suggested to:

"E*ducate agents about proper lifting techniques, perform stretching exercises, use heavy tags to create awareness*, p*ark carts within three feet of beltloaders to minimise carry distances and use hand trucks or carts to move large and heavy bags over long distances*".

For manual handling in aircraft baggage compartments, the following advice was given in the OSHA e-tool:

"*Educate agents about proper lifting techniques*, p*erform stretching exercises, alert the loading and unloading crews when heavy bags are coming, slide baggage close to the body before lifting, minimise twisting, kneel on both knees, or balance on one knee and one foot and stack large bags on the bottom".*

This was good sound advice for inclusion in a safety induction for new start baggage handlers, but as the literature and biomechanical modelling in this study showed, unlikely to make much impact on the rate of baggage handler injuries. Its clear that other more long term strategies will be needed to actually turn around the baggage handler injury rates in the USA reported by the OSHA/Airlines Industry Ergonomic Alliance (OAIEA (2004) described in Chapter 1.

In fact, the OAIEA presentation at the 2004 US National Safety Congress (*OAIEA (2004)*) revealed not one new engineering intervention was offered.

In the USA it seems, there's still a long way to go to find effective solutions, a dubious situation since it was the airline members of the US National Safety Council Air Transport Executive that first identified and researched these same issues in 1977 (*ARTEX (1981)*).

In 2002, the UK Health and Safety Executive published equivalent advice to that of OSHA for baggage handlers working in the existing baggage handling environment (*HSE(2002)*). All the same short term administrative solutions were offered. More recently, HSE published the results of an assessment titled "*Baggage Handling in Narrow-Bodied Aircraft: Identification and Assessment of Musculoskeletal Injury Risk Factors*" (*Tapley and Riley (2005)*). The risk reduction measures recommended by *Tapley and Riley (2005)* were extensive but included the same advice focused on administrative controls:

"*Job rotation to reduce exposure to stacking operation, reduced bag weights and frequency of handling, tugs should be used to move the baggage carts around the aircraft, powered belt loaders eliminate the need for pushing and pulling and would be the preferred equipment rather than manual belt loaders, reduce need to handle above shoulder height/below knee height, eliminate direct to hold loading practice, reduce the height of top layer of bags on carts and task specific training for handling inside hold to be included in manual handling training*"

Tapley and Riley (2005) also recommended*:*

"…include using heavy bags as the base of the stack to reduce the need to lift bags into place, belt loaders to be used for all 737 series aircraft baggage handling operations, eliminating direct to hold loading practices".

"Specific training, improved bag labelling and information from check in staff and decrease handling frequency" were also part of the recommended strategies*.* However, the authors showed a possible lack of understanding the underpinning cultures and economic realities of many airlines by suggesting the reduced handling frequencies could be achieved by "…*increasing. load/unloading time or by increasing numbers of handlers so each member of staff handled fewer bags".* Both these measures are optimistic at best and highly unlikely to be applied voluntarily by airlines struggling for a competitive advantage against equally competitive rivals.

The medium to long term interventions suggested by *Tapley and Riley (2005)* were:

"Passenger education about weight and size of luggage at point of sales, industry education e.g. travel agents, travel press, establish dialogue with baggage manufacturers" and *"…reduce bag weight limit from current 32kg limit based on research".*

Clearly, all these solutions are at the wrong end of the hierarchy of hazard control and unlikely to deliver lasting baggage handler injury reductions. Perhaps its not surprising that the aircraft manufacturers and the airlines haven't taken up these well known principles of reliable hazard control, since neither has the majority of OH&S regulators.

After listing twenty administrative control options, *Tapley and Riley (2005)* finally suggest changing the engineering design: "…*develop technology to reduce risks"* and ultimately get to the heart of the problem and suggest "…p*lane design to eliminate the need for manual loading/unloading operations."*

Tapley and Riley (2005) represents as good a summary of the twenty-five years of literature reporting on the application of administrative solutions. It seems that since the original *ARTEX (1981)* study, authors have predominantly recommended administrative interventions for the baggage handling injury problem.

Even the further research recommended by *Tapley and Riley (2005)* failed to consider long term engineering solutions…"e*stablish an industry forum to review and research and develop alternative methods of loading/unloading, undertake a musculoskeletal health survey of baggage handlers and undertake an in-depth study of aircraft baggage handlers using approaches such as the RPE scale, heart rate, etc, to investigate the effect of workload and to measure the exertion associated with sliding / throwing items the length of the hold".*

The biomechanical loading and ergonomists opinions reported in this study, which clearly indicated the postures adopted by baggage handlers in narrow-body aircraft represented a high risk of back injury would partly satisfy these recommendations for further research. However, again leaving the best until last *Tapley and Riley (2005)* further recommended "…*make a direct comparison of work practice and MSD risks with traditional methods versus the use of the RampSnake and or similar equipment"*, a recommendation which if applied, has the potential to validate a significant engineering contribution to baggage handler injury prevention.

The literature shows that the majority of the other suggestions of *Tapley and Riley (2005)* have been known about and applied by the airlines, albeit sometimes poorly, for many years. Every time the baggage handler injury rates have spiralled upwards, there's been a call for "*better training*", "*limit the weight of bags*", "*ensure the baggage handlers understand their limitations*", "*use two person lifts*", etc.

The airlines at the fore in safety management, such as Qantas, Delta, SAS, KLM and many others have been doing these things for years (see *Smidt (1998), ARTEX (1995), Gaber (1998), Berubé D. (1996), Briggs D. (1997),* *Darby (1994), Dell G. (1997), Dell (1998)* and *Hogwood (1996)*), and the injury rates and associated costs (see *Culvenor (2004) OAIEA (2004)* and Korkmaz er al (2006) appear to have continued unabated.

Based on the outcomes of this research project, the time has come to acknowledge that "*administrative solutions alone are not effective enough to provide a solution to the high risk manual handling work of airline baggage handlers*" At best, they may have prevented the problem from worsening.

The time for committees, alliances and talk should be at an end. The technology now exists to significantly reduce the baggage handler injury risk once and for all.

In the aircraft, containerisation and mechanisation must be the way of the future. Airbus has shown it's possible with its A319/A320 design. If *Sliding Carpet* and *ACE* are part of an airlines intervention, then they should be used in conjunction with the RTT Longreach Loader or RampSnake. Indeed, RampSnake itself maybe used as a stand alone solution to loading bulk baggage compartments.

In the airport terminals mechanical lifting aides or robotics to load containers and barrows should be the norm in future, if baggage handler injuries are to become a thing of the past.

Unfortunately, without regulatory intervention, the talk will probably continue into the future. As (Briggs (1997) suggested "…*there has to be the will in the industry*" if the design changes are to occur. However, after twenty-five years of talk, with a few notable exceptions, it seems the will has yet to be found.

The global OH&S Regulators must follow the DWES lead. It's the way forward if a safe design paradigm shift is to occur in this area in the medium to long term future. The regulators must provide the incentives for the industry to make the step change needed. If encouragement hasn't worked, sanctions may be needed.

4.3 SATISFYING THE OBJECTIVES OF THIS PROJECT

The objectives of this project, detailed in Table 2.1 in Chapter 2, have been satisfied as follows:

Objective 1: Engaging the major jet passenger transport aircraft manufacturers and industry associations in the issue of baggage handler back injuries

The Phase 1 meetings and presentations with the major aircraft and ground equipment manufacturers placed the issue of baggage handler injuries on their agendas. They resulted in Boeing and Airbus becoming regularly involved in the Ergonomics Committee of the National Safety Council of America International Air Transport Executive (ARTEX) where the issue has been the regular subject of discussion.

Objective 2: Investigating awareness of the issue amongst international safety organisations

The support of the National Safety Council of America International Air Transport Executive was achieved early in the project. ARTEX had published the quintessential research into the matter in 1981 and were eager to continue pursuing the matter. In 1994, ARTEX appointed the writer to Chair its Ergonomics Sub-Committee to pursue the matter further. Up to June 1996, when the Chair transferred to Mr Doug Briggs the new Boeing representative on ARTEX, the writer formally reported progress on this research project to the full ARTEX Executive Committee every six months (see ARTEX January 1996 Agenda at Appendix No 33 for example).

In addition to the nineteen formal presentations made at seminars around the world (see Appendix No 2), industry workshops were held in Brussels Belgium (June 6, 1995), Sydney Australia (January 25, 1996), Calgary Canada (June 20, 1996) and Atlanta USA (January 1997) (see Appendices Nos. 34 , 35, and 36).

Finally, a paper summarising the literature in relation to the baggage handler back injury problem (*Dell (2004)*) was presented to the February 2004 Branch Seminar of the Human Factors and Ergonomics Society of Australasia to encourage interest in the subject amongst Australian ergonomists and to gain their support in participation in the Phase 4 CPE survey (a copy of the paper is at Appendix No. 37).

Recently, papers from this research project have been summarised and referenced in the publications of two large OH&S regulatory agencies, the UK Health and Safety Executive (*Tapley and Riley (2005)*) and the US Occupational Safety and Health Administration (*OSHA 2003)*).

Objective 3: Encourage aircraft ground support equipment manufacturers to investigate the issue and develop solutions technologies

The meetings of the Ergonomics Sub-committee of the National Safety Council of America International Air Transport Executive regularly included representatives of the relevant ground equipment manufacturers, in particular the Scandinavian Bellyloading company, the manufacturer of *Sliding Carpet* and the *RTT Longreach Loader* (see Appendix 53, Attachment No, 1) and Air Cargo Equipment the manufacturers of *ACE*.

Objective 4: Investigate the costs of baggage handler back injuries in the world's major airlines

Phase 2 of this project established the costs and magnitude of the problem and the resultant paper *Dell (1997)* was the first time information of this type had been published in the literature.

Objective 5: Canvass the opinions all the airlines' safety professionals regarding the causes and prevention of baggage handler back injuries

The meetings of the Ergonomics Sub-committee of the National Safety Council of America International Air Transport Executive provided an ongoing opportunity to canvass opinions of airlines' safety professionals on this issue. Their input was formalised with the Phase 2 survey, the results of which were published in *Dell (1997)*.

Objective 6: Survey the opinions of a cross-section of baggage handlers worldwide regarding the causes and prevention of baggage handler back injuries

The Phase 3 survey of baggage handler opinion determined the workforce's concerns in this area. The results of that survey were published in *Dell (1998)*.

Objective 7: Compare the effectiveness of the *ACE* and *Sliding Carpet* narrow body aircraft baggage systems

The substantive trials conducted in the B737 baggage compartment mock-up that was constructed in the Human Movements Laboratory at the University of Ballarat, in Phase 4 of the project, measured the differential ergonomic impact of the two systems on baggage handlers. Multiple measures of the differences were carried out to ensure corroboration of the outcomes.

The results of Phase 4 of the research, including the results of the ergonomists opinion survey, has been reported in Section 3.4 of this Thesis and will also be published in a subsequent journal article in a peer reviewed journal.

Objective 8: Assess the change in manual handling risk associated with the use of the prototype *RTT Longreach Loader* that was designed to reduce the need for baggage handlers to lift baggage and cargo when lighting or unloading narrow body aircraft

Phase 5 of the research project involved a risk assessment of the manual handling risks of the RTT Longreach Loader. It was a collaborative assessment involving baggage handlers from Qantas Airways and the RTT manufacturer Telair Scandinavian BellyLoading Co. AB. The results have been reported in this Thesis and will be subject of a subsequent paper in an appropriate peer reviewed journal

Objective 9: Develop a series of recommendations to reduce the occurrence of back injuries in the airline baggage handler workforce

The Conclusions and recommendations of this research project are described in Chapters 5 and 6.

4.4 CONTRIBUTIONS TO KNOWLEDGE

This project was the first occasion upon which the baggage handler injury issue was raised with the major aircraft manufacturers whose aircraft designs were central to the injury causation problem. Also, the frequency of baggage handler back injuries and the direct costs in dollar terms had not been previously surveyed across a number of airlines globally and the results published.

In addition, prior to this project, neither the safety professionals working in the global airline industry nor the people working in the at risk group, the baggage handlers working in airlines around the world, had been surveyed for their opinions of on baggage handler back injury causation and prevention and the results published.

The controlled laboratory trials in this study that were conducted to measure the effect of using *Sliding Carpet* and *ACE* baggage systems on the risk of back injury to people stacking baggage inside narrow-body aircraft baggage compartments was the first time trials of these systems were undertaken where the methodology was specifically designed to isolate the aircraft baggage compartment configuration as the sole dependent variable.

This study was also the first time that video MPEGs were used to present 3D dynamic moving images of worker postures so that a statistically large enough sample of ergonomics specialists could provide opinions on variations in postural risk of the workers. This method allowed the workplace activity to be taken to a large group of specialists to add rigour to the analysis, without losing the dynamics of the loading process and providing the specialists with subject matter devoid of the researcher bias that can occur when still photographic images, the method often used in the past for gathering the opinions of large numbers of specialists, are selected by the researcher.

Also, as a result of this methodology, this project was the first occasion a statistically significant population of ergonomics experts had provided opinion on the effect of the use of *ACE* and *Sliding Carpet* on the risk of back injury to people stacking baggage inside narrow-body aircraft baggage compartments.

This was also the first time, because of the study design, a statistically significant consensus of specialist ergonomist opinions corroborated the results of 3D biomechanical modelling of baggage handler working postures.

Finally, at the time the formal risk assessment in Phase 5 of this study on the effect of using the prototype RTT Longreach Loader on the manual handling injury risks associated with stacking baggage inside narrow-body aircraft baggage compartments, the manufacturer had not conducted any risk assessment activity on the prototype. Accordingly, the risk assessment conducted in this study, which involved experienced baggage handlers trialling the system and then applying proven risk analyses techniques, directly informed the ongoing design activity and positively reduced the level of residual risk transferred to subsequent end users of the loader in service.

4.5 THE LESSONS FROM THIS PROJECT WITH APPLICATION BEYOND THE AIRLINE BAGGAGE HANDLING DOMAIN

This study of airline baggage handler back injury causation and prevention revealed a number of lessons that have application broadly to other industries and other injury prevention and risk management domains.

The experience with some of the aircraft manufacturers in this study showed that to ensure equipment manufacturers take responsibility for the residual risks associated with their designs, it is important that injuries associated with those designs are clearly and concisely documented and published. The need for this has been known for many years and also suggested by earlier authors (see *Lundgren et al (1988)* and *Oxenburgh (1991*).

Furthermore, equipment designers maybe unwilling to alter their designs retrospectively unless their market demands change and solutions which don’t require design change maybe favoured by them without rigorous validation of the effectiveness of those solutions being carried out. This was also reported by *Briggs (1997)*.

Coordinated action by industry and government agencies may also be necessary to create a climate for serious effort to be expended in developing reliable engineering design solutions. The work of the Danish Work Environment Service (*DWES (1999)*) provides an example of the possible benefits. Otherwise high residual risks associated with inadequate designs may be controlled ineffectively by relatively vulnerable administrative interventions for the duration of the life of the plant.

Also, the inadequate design features of one generation of plant may be transferred to the design of the next generation of the plant, unless the shortcomings of the original are clearly identified and end-user criticisms consolidated and published to aid development of demand for design solutions.

Indeed, the costs associated with injuries, in dollar terms, are an essential element of convincing manufacturers that there are shortcomings in their designs which may require re-engineering, before real attempts to achieve effective solutions will occur.

To inform the conduct of future postural studies, especially in environments where test equipment may be affected adversely by radio interference, or where viewing access is difficult, this study showed the consensus of ergonomics specialist opinions can be relied upon to identify subtle variations in postural risk in workplace applications. This methodology could be applied in any work or other environment where trials using complex measuring equipment may be problematic, costly or prohibitively time consuming to perform. This study validated ergonomists opinions with biomechanical modelling and measurement of postures.

This project also showed that when the workers exposed to hazards and the safety professionals observing those hazards in operation reach consensus regarding the significance of the hazards and methods for intervention, it should be unnecessary to expend further resources assessing the hazards but rather efforts should move on to investigate and implement effective hazard controls.

Finally, it was clear from the results of this project that in operations with high risk manual handling activities, injuries rates may not be sufficiently reduced using administrative interventions such as lifting technique training, two person lift policies, task rotation and moderate weight limits. Where the biomechanical loads associated with the tasks are high, engineering design interventions will be necessary to reduce the risks to an effective level or to eliminate exposure to those risks permanently.

CHAPTER FIVE CONCLUSIONS

This study showed that injuries to airline baggage handlers have for some time been a problem of epidemic proportions. Unacceptably high injury rates have been occurring for decades and continue unabated.

Some OH&S regulators, safety professionals, airlines and most baggage handlers continue to press for enhancement of administrative hazard controls such as training, mediocre baggage weight limits, shared workload practices and lifting techniques. This study has shown that these administrative interventions have failed to stem the tide in the past and, due to the high musculoskeletal loads imposed by the work, are unlikely to do so in the future.

The evidence is overwhelming that manual lifting of baggage and cargo must be eliminated from the airline baggage transfer process, if a significant and sustained reduction in injury rates is to occur. Much more effort needs to be expended to find mechanical solutions to each of the manual baggage handling tasks that have been the accepted airline industry norm for over 70 years.

ACE and *Sliding Carpet* have eliminated one such task, the transfer of baggage from the doorway of narrow body aircraft to the person stacking baggage within the compartment.

However, neither system addressed the task that the end users, the industry safety professionals and the researchers agreed was the highest injury risk, that of stacking baggage inside the narrow-body aircraft baggage compartment in which they were installed. This study showed that the biomechanical load on the lower backs of baggage handlers stacking baggage into *ACE* was significantly higher and therefore the injury risk was also proportionally higher, than if no system at all was fitted to the aircraft. In the case of *Sliding Carpet*, this research showed that the low back loading on baggage handlers stacking baggage into *Sliding Carpet* were slightly higher than when stacking baggage inside the narrow-body aircraft baggage compartment in which they were installed.

Furthermore, this study revealed that the postures adopted by baggage handlers stacking baggage into both *ACE* and Sliding Carpet when the inward opening aircraft door impacted on the baggage handlers' work space to the extent that it adversely altered worker posture, were a higher risk of back injury than when stacking baggage inside a narrow-body aircraft baggage compartment with no system installed.

In these respects, *ACE* and *Sliding Carpet* should be considered first generation solutions and the search for interventions which eliminate the lifting and stacking tasks should persist. Continuing to rely on personnel to lift and stack baggage and cargo in these aircraft baggage compartments without doing so, in the face of the mounting evidence of the related high and poorly controlled injury risks would be poor business practice and a moral dilemma.

Without effective engineering intervention, the baggage handling injuries and the losses directly associated with them will continue unabated.

New equipment designs, such as the prototype RTT Longreach Loader assessed in this study and the RampSnake loader reported in the literature, appear to be a significant step in the right direction. However, more research is needed. The injury prevention benefits of these systems need to be fully explored and evaluated while other interventions for this and other baggage handling tasks also need to be sought.

In this respect, the OH&S Regulators and airline safety professionals have a key role. They must a lead a change to the industry culture which at present inappropriately considers manual handling to be an acceptable baggage and cargo transfer method.

However, for this culture change to occur, all the OH&S Regulators and the safety professionals must first make the ideological leap and acknowledge that years of administrative control attempts have failed to stem the tide and are most likely to continue to fail in the future.

This study has shown the high biomechanical loads on baggage handlers in the present working environment are far too high for administrative controls to be effective and lasting solutions.

Specific Conclusions Related to the Phases of this Project

Conclusions in Relation to the Manufacturers

At the time this research project began the aircraft manufacturers were unaware of the problem of manual handling injuries to airline baggage handlers. While none of the aircraft manufacturers were taking any action which may impact on manual handling injuries to airline baggage handlers, all pointed to the *ACE* and *Sliding Carpet* systems as possible solutions, since both had been reported to reduce the number of baggage handlers required to load an aircraft baggage compartment, thus theoretically reducing exposure to injury.

At the time, none of the manufacturers were willing to review their aircraft baggage compartment designs

With the exception of those manufacturers who went out of business, or were subject to takeover, all the manufacturers participated in activities to help develop lasting solutions to the problem of manual handling injuries to airline baggage handlers.

Some aircraft design team representatives of some of the manufacturers felt the problem of manual handling injuries to airline baggage handlers and its solutions were not an area of interest to the manufacturers.

The aircraft manufacturers were not factoring airline baggage handler injury costs into life cycle cost projections for their aircraft designs

All manufacturers felt that airport terminal and baggage systems designs were a matter for the airlines and airport owners.

All manufacturers wanted to obtain more definitive information concerning the costs and magnitude of the problem manual handling injuries to airline baggage handlers

Conclusions in Relation to the Magnitude of the Problem

Back injuries to airline baggage handlers represented a significant cost[46] to the sixteen airlines that participated in this phase of the research: $US 17,639,857 in 1992 to $US 23,697,170 in 1993 and $US 21,710,953 in 1994.

Based on the data from the airlines that participated in this study, lost time injury frequency rates per million hours worked were 42.5 for 1992, 41.5 for 1993 and 43.5 for 1994. These results were over forty times worse than reported injury rates in best practice organisations.

The average cost of an airline baggage handler back injury was $US 11,236 in 1992 to $US 9,841 in 1993 and $US 9027 in 1994, based on the data from the airlines in this study.

Evidence from the literature indicated the incident rates and costs have escalated since the time this research project began.

Conclusions in Relation to the Input of Airline Safety Professionals and Baggage Handlers

Airline Safety Managers and baggage handlers ranked "*Inside Narrow Body Aircraft Baggage Compartments"* as the workplace most likely to be the site of a back injury and the managers ranked "*Stacking Baggage inside the Baggage Compartments of Narrow Body Aircraft*" as the highest risk baggage handling task. Baggage handlers ranked that task a close second behind the other task in narrow-body aircraft *"Pushing Bags from Doorway into Narrow Body Compartment*"

[46] Airlines were requested to include all compensation, medical expenses and rehabilitation costs.

Heavy baggage was identified as a significant problem by the airline safety managers and baggage handlers surveyed in this study.

Many of the safety managers and baggage handlers in this study wanted an industry baggage weight limit set and enforced. However, recent research indicates that to be affective as an injury prevention measure, a limit would have to be set below 10kg which would probably be commercially impractical.

Only two of the airlines in this study had used back support belts in the baggage handling workforce. However, one reported no change in injury rates with the belts in use, consistent with the findings of many other studies of back belt use reported in the literature. However, the other airline reported a 60% reduction in injury rates which would seem to be dubious based on the plethora of evidence in the literature to the contrary.

Training in lifting techniques and back care were in place in the baggage handling areas of twelve of the sixteen airlines. Although only two companies reported any resultant improvement in baggage handler back injury rates, ninety percent of baggage handlers in this study wanted better manual handling training. This apparent disconnect between past results and end user expectation would benefit from further research and explanation.

None of the airlines surveyed in this study provided mechanical lifting aids in baggage rooms for the use of their baggage handlers.

Only half of the baggage handlers considered conveyor belts in their baggage rooms were of adequate height

Nearly half (46%) of the baggage handlers surveyed in this study had experienced a back injury while handling baggage in the past. Over half of those (55%) felt that their back injuries reduced their ability to carry out the work and sixty percent of them reported that their injuries had recurred at least once.

All of the baggage handlers in this study who had worked with narrow-body stacking systems, such as *ACE* and *Sliding Carpet*, preferred loading aircraft fitted with the systems.

Development of in-plane baggage and cargo stacking systems for narrow-body aircraft was the most popular redesign solution offered by the baggage handlers in this study

Conclusions in Relation to the Laboratory Trials of *ACE* and *Sliding Carpet*

In the trials conducted in a B737 baggage compartment mock-up to evaluate the relative back injury prevention effect of the *ACE* and *Sliding Carpe*t narrow-body in-plane systems, biomechanical modelling using the Michigan 3D Static Strength Prediction Program found that stacking baggage into narrow body aircraft baggage compartments, regardless of the type of system fitted to the compartment, or when no system was fitted, resulted in mean disk compression forces in the subjects' lower backs in the range 3300 to 6200 Newton representing a significant back injury risk to baggage handlers, especially considering the repetitive nature of their work and accumulative effect of such exposures.

Stacking baggage into *ACE* resulted in statistically significant higher disk compression forces in the lower back and therefore significantly higher back injury risk, than when stacking baggage in *Sliding Carpet*. Mean L4L5 disc compression forces for *ACE* were 6202 Newton, compared to 5501 Newton mean L4L5 disc compression force for *Sliding Carpet*. Also, mean L5S1 disc compression forces for *ACE* were 4433 Newton, compared to 3313 Newton mean L5S1 disc compression force for *Sliding Carpet*.

Also, stacking baggage into *ACE* resulted in statistically significant higher disk compression forces in the lower back and therefore significantly higher back injury risk, than when stacking baggage into an aircraft baggage compartment without a system fitted. The mean L4L5 and L5S1 disc compression forces measured for "No System" configuration in this study were 5239 and 3627 Newtons respectively. Based on these measures, the *ACE* system resulted in the highest risk of back injury to both the other baggage compartment configurations.

In the comparisons of loading baggage into *Sliding Carpet* against loading baggage into a B737 aircraft compartment without any system fitted, these mean disc compression forces also showed that the differences were not statistically significant.

Direct measurement of the freeze frame images of postures adopted by baggage handlers in this study found that stacking baggage in *ACE* resulted in statistically significant further reaching while stacking, with mean distance of 113cm versus 95cm, and therefore significantly higher back injury risk, than when stacking baggage in *Sliding Carpet*. Stacking baggage in ACE also resulted in statistically significant further reaching while stacking, with mean distance of 113cm versus 91cm, and therefore significantly higher back injury risk than when stacking baggage into an aircraft baggage compartment without a system fitted.

There was no statistically significant difference in reach distances exhibited by baggage handlers when loading baggage into *Sliding Carpet* compared to loading baggage into a B737 aircraft compartment without any system fitted with mean distances of 95cm versus 91cm respectively.

There was no statistically significant difference in trunk rotation exhibited by baggage handlers when stacking baggage in *ACE*, in *Sliding Carpet* or when stacking baggage into baggage compartment of B737 dimensions without any stacking system fitted. The degree of trunk rotation was considered to be a function of fuselage width geometry rather than contingent upon whether a stacking system was fitted or not.

Observation of aircraft loading activities of the many airlines that participated in this study confirmed that both ACE and Sliding Carpet eliminated entirely one baggage handling task, that of pushing baggage into and out of the interior of the narrow-body aircraft baggage compartments. Accordingly, both systems proportionally reduced exposure of baggage handler to injury risk.

Conclusions in Relation to the Opinion of Ergonomists

The ergonomics specialists who participated in this study made a statistically significant greater number of decisions that baggage handlers stacking baggage into *ACE* exhibited postures with higher risk of back injury than when stacking baggage in *Sliding Carpet*.

A statistically significantly greater number of decisions were made by the ergonomists that baggage handlers stacking baggage into a baggage compartment of B737 aircraft baggage compartment without either *ACE* or *Sliding Carpet* fitted, exhibited postures with lower risk of back injury than when stacking baggage in *Sliding Carpet*.

Analysis showed that this was due to the presence of the inward opening aircraft door encroaching on the workspace and the door affecting baggage handler postures to the extent that ergonomists made a statistically significantly greater number of decisions that the postures adopted in a compartment without any stacking system fitted were a lower risk than those in a compartment fitted with Sliding Carpet

Conclusions in Relation to the RTT Longreach Loader and other mechanical aides

The RTT Longreach Loader significantly reduced the ergonomic load and resultant back injury risk of baggage handlers stacking baggage into narrow-body aircraft. Lifting of baggage in the narrow-body baggage compartment was virtually eliminated by the RTT Longreach loader.

Container systems with removable tops or doors in the tops, should be developed for all aircraft types, like those for the A320, that allow mechanical lifting aids to be effectively applied by baggage handlers

The literature shows that effective robotics technologies have been successfully trialled for baggage room applications.

Conclusions in Relation to Industry Culture

There has been considerable inertia in the airline industry over the past quarter century, an apparent reluctance to adopt effective baggage handler injury prevention interventions. A penchant has existed for soft administrative interventions which have seen the injury rates and costs continue to climb.

The ergonomic risks associated with traditional baggage handling methods are so high that administrative controls, such as manual handling training, two person lifts and weight limits the industry is commercially willing to accept, will never solve the problem. These methods have been applied for over twenty-five years and the injury rates and costs climb on.

Recent action by the American and UK OH&S regulators which has involved reformation of aviation industry discussion forums to investigate solutions to the baggage handler injury problem, have focused their effort on making yet further calls for the same administrative interventions which have been tried in the past and have been shown to have limited injury rate reduction effect.

Strong intervention by the Danish Work Environment Service which imposed short term administrative controls and mandated a medium term goal of re-design solutions to eliminate the manual handling of baggage and cargo, has provided the model for other jurisdictions to emulate. The Danish action led directly to new workplace and loading equipment designs which have largely eliminate manual lifting of baggage and cargo, including inside the baggage compartment of narrow body aircraft.

The Danish experience has provided the example which should be followed by all other OH&S regulators globally. As the industry itself seems unable to deliver effective solutions, global regulatory interventions should focus on similar design solutions with the same vision: To eliminate entirely the manual lifting of airline baggage.

The lessons from this baggage handling injury prevention project concerning the long term ineffectiveness of administrative controls and the contrasting benefits of design interventions which eliminate manual lifting should be applicable in other workplaces with high risk manual handling activities.

This project showed that it was possible to engage the major stakeholders in a global industry, the manufacturers of plant and equipment, industry bodies, unions, companies and workers to apply pressure for injury prevention improvements. However, there was inertia against rapid improvements that had to be overcome in order to create a step change across the global airline industry.

CHAPTER SIX: RECOMMENDATIONS

RECOMMENDATIONS FOR FURTHER RESEARCH

There are many aspects of baggage handling injury causation and prevention that would be worthy of further research. For example, the airline industry culture of widespread reliance on administrative hazard control measures for mitigation of baggage handler injuries that have been at epidemic proportions for many years would make a valuable contribution to knowledge.

This study revealed there is very little evidence of critical analysis of some of the claims of successful administrative interventions. All too often it seems, companies have simultaneously introduced many supposed solutions, for example simultaneously altered training, changed work practices and introduced new equipment, and then claimed positive results. Better controlled studies of the issues are needed to sort out which are really solutions and which are just confounders.

Further study would be beneficial to fully understand why some airline safety managers continue to favour administrative controls in this area, despite the mounting evidence that they are inadequate.

Ninety percent of baggage handlers surveyed in this study wanted better manual handling training. This apparent disconnect between past results and end user expectation would benefit from further research and explanation.

The baggage hander injury reduction benefit of the RTT Longreach Loader and RampSnake Loader should be investigated further. Control trials using contemporary computer modelling programs or surface EMG techniques would be beneficial to confirm the benefits of the systems predicted in the analyses reported in the study.

Any future trials to differentiate workloads associated with loading baggage into narrow-body aircraft should ensure trial durations are of sufficient duration for participant heart and oxygen consumption rates to plateau during the work sequences and provide a differential measure of workload.

Also, the results of this study relied heavily on expert opinion and computer modelling of baggage handler postures. Further analysis of injury risk using contemporary measures such as surface EMG, with baggage handlers loading aircraft in line operations would be invaluable. Of course, future researchers would need to solve the problems of electrical interference from the live aircraft systems.

With the exception of this study, very little work has been done to ascertain the opinions of the baggage handlers themselves. There are opportunities to use subject self evaluation models such as Mort, to sharpen the focus on the under-pinning issues and their significance.

Also, this study focused on the baggage handler back injury phenomenon. Both the injury data and the literature indicated baggage handlers' injuries also include shoulder, neck, hand, arm, leg and knee clusters. These would also be worthy of further analysis.

Finally, a new group of ground support equipment is now emerging in the airline industry, such as RTT and Ramp-snake intended to address some of the high risk baggage handling tasks remaining in the industry. Its uptake by the industry appears lethargic. These and other mechanical solutions require further scientific study in order to ensure their true value is understood and their benefits are maximised.

RECOMMENDATIONS FOR INDUSTRY CHANGES

The OH&S Regulatory agencies should take action to ensure the aircraft manufacturers fully understand their product liability obligations and their responsibilities under contemporary OH&S legislation as designers of plant and equipment used in the workplace.

All OH&S Regulators should ensure the airlines in their countries are aware of the serious problem manual handling injuries to airline baggage handlers represent and of the significant costs these injuries incur.

The aircraft manufacturers should ensure that airline baggage handler injury costs are factored into the life cycle cost projections for their aircraft designs.

Due to the upstream influence of aircraft systems design on airport and baggage systems design, the manufacturers should ensure the airlines and airport owners understand the issues surrounding manual handling injuries to airline baggage handlers.

Aircraft manufacturers should take action to ensure the risks associated with the baggage compartments of their narrow-body aircraft are effectively controlled either by changing the aircraft design to reduce the risks or by ensuring their customers are aware of the need for after-market solutions.

Future narrow-body aircraft designs should incorporate systems that eliminate the need for baggage handlers to lift and stack baggage in the restricted confines of the aircraft baggage compartments.

Airport terminal baggage system designs in future need to ensure appropriate adjustability of conveyor and other equipment to maximise the ergonomic advantage for all baggage handlers.

Future baggage systems should be designed so that mechanical lifting devices can be employed to reduce significantly the manual handling load on baggage handlers

Airlines that have *ACE* or *Sliding Carpet* systems fitted to their aircraft should introduce contemporary loading systems, such as the *RTT Longreach Loader* or *RampSnake,* to reduce the ergonomic load on their baggage handlers working in narrow-body aircraft.

As an interim measure, airlines should ensure baggage handlers are aware of the postural hazards resulting from inward opening baggage compartment doors and training should include methods of stacking baggage to avoid hazardous postures resulting from the influence of the door. It may be necessary to avoid altogether loading baggage immediately beside the door when stacking near the baggage compartment ceilings.

All airlines should consider introducing a combination of technologies such as robotic baggage container stacking machines or mechanical lifting aids in baggage rooms, RTT Longreach Loaders or RampSnake Loaders for narrow body aircraft loading and Sliding Carpet or ACE narrow-body in-plane stacking systems. The optimum combination of these rapidly developing technologies should permanently eliminate manual baggage handling and its associated high costs.

The global OH&S regulators should apply pressure to their respective airlines to adopt the more effective engineering solutions now emerging rather continue the administrative control regimes of the past which have had limited benefit.

The true costs of baggage handler injuries need to be clearly identified. There is a role for all the workers compensation fund managers to ensure the costs of baggage handling injuries are made prominent, although there will probably be a need for improvements in data coding and reporting and in many jurisdictions before the true magnitude of the problem and associated costs will emerge.

All industries and workplaces with a reliance on manual handling methods, especially where heavy weights are routinely lifted, should consider the outcome of this research which in part showed that effective injury prevention solutions will no doubt be the result of design interventions which eliminate manual handling rather than administrative controls which perhaps lessen the impact of the manual handling but do not have the capacity to deliver lasting and effective injury reductions.

GLOSSARY

Term/Abbreviation	Meaning
ACE	A baggage system manufactured by American company Air Cargo Equipment Inc which has been fitted to the baggage compartment of some narrow-body aircraft. Sometimes described as a “nesting system, it comprises a series of concertina bins which allow the compartment to be loaded by a single person working inside the compartment near the doorway.
bpm	Heart rate measure “beats per minute”
Check-in	The location at an airport where passengers register for a flight and lodge their baggage with the carrier
hazard	For the purposes of this study, the term hazard applied to any feature of a process, activity or item of plant that had the potential to cause harm to baggage handlers
LTIFR	Lost Time Injury Frequency rate is the number of injuries resulting in staff failing to return to work at their next work shift following an injury. It is measured often as the number of injuries per 10^6 hours worked, although in some countries other denominators are used.
Manual handling	Manual handling means the physical lifting, pushing and pulling of items with the hands
Michigan Program	Biomechanical modelling software named the University of Michigan 3D Static Strength Prediction Program
N abbreviation for Newton	Unit of measure for force eg spinal compression force
Narrow-body aircraft	Single aisle passenger transport aircraft such as the Boeing B717, B727, B737, McDonnell Douglas DC9, MD83 and MD87 and Fokker F28 & F100, as well as all commuter aircraft, seating up to around 150 passengers, that are designed to have the baggage loaded in bulk, one item of baggage at a time

N/R	Nil response
“No System”	The configuration of the mock-up which simulated the circumstance of a B737-400 baggage compartment, Compartment No. 3, without any baggage stacking system installed. The dimensions were taken from Boeing specifications and by direct measurement of aircraft at Melbourne Airport
OH&S	Occupational Health and Safety
Ramp	The area of an airport usually reserved for parking aircraft for the purposes of loading and unloading passengers, baggage and cargo, as well as servicing and maintenance activities in preparation for the next flight.
RHR	Measured lowest resting heart rate
Sliding Carpet	A baggage system manufactured by Telair Scandinavian Belly Loading AG which has been fitted to the baggage compartment of some narrow-body aircraft. Sometimes described as a “nesting system, it comprises a continuous belt and moving wall which allow the baggage compartment to be loaded by a single person working inside the compartment near the doorway.
Peak Work Heart Rate	The heart rate considered to be a measure of work demand calculated by subtracting the measured resting heart rate from the working heart rate measured in beats per minute (*see Grandjean (1988)*)
Widebody aircraft	Twin aisle passenger transport aircraft such as the Boeing B747, B767, & B777, Airbus A300, A310, A330 & A340, Lockheed L1011 and the McDonnell Douglas DC10 & MD11, each seating in excess of 200 passengers, are fitted with containerized baggage systems

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LIST OF APPENDICES

APPENDIX NO. 1

1994 DISCUSSION PAPER: "*Airline Baggage Handler Back Injuries: Our Prevention Obligations*

AIRLINE BAGGAGE HANDLER BACK INJURIES:

OUR PREVENTION OBLIGATIONS

presented by

GEOFF DELL
MANAGER SAFETY MELBOURNE
QANTAS AIRWAYS

at

AAGSC Ramp Safety Workshop, December 8, 1994

SYNOPSIS

Back injuries to airline baggage handlers cost the aviation industry millions of dollars per annum. Some airlines have over 20% of their baggage handler workforce absent due to back injuries at any one time. Many of these injuries are debilitating and result in long term suffering and sometimes permanent reduction in quality of life.

Most past efforts to address this issue have been focused on behaviour control, lifting technique training and procedural variation. There has been few attempts to determine engineering solutions to the problem. This has possibly been due to the peculiarities of design and operation of modern transport aircraft, inconsistencies of standards and policies applied by the airlines, and the apparent failure of traditional manual handling methodology in this application.

Occupational Health and Safety Professionals in the aviation industry have an obligation to take up the challenge to address this issue. There is a need to seek real solutions to the problem and address aircraft and ground equipment design and serviceability and develop more realistic international baggage and cargo weight and size standards.

If we don't achieve a satisfactory result, the labour force will impose sanctions on the industry which will be far less palatable and more expensive than any solutions our profession may consider, however complex and hi-tech they may be.

Some airlines are begining to grasp this issue, but many are not. We OH&S Professionals can no longer afford to turn an apparent blind eye, just because solutions are not easy to achieve.

INTRODUCTION

The airline ramp operation is largely a materials handling function. While there has been significant effort expended to implement engineering solutions to cope with the volume of

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baggage and cargo, there has been very little success in development of solutions to reduce exposure to manual handling risks in the ramp work force.

Containerisation has solved the volumetric problem but is only of limited value in preventing manual handling injuries.

Many airlines routinely expend millions of dollars per annum on manual handling injuries amongst airport staff. Such losses, even without the additional consideration of the suffering and social impact these often debilitating injuries cause, cannot, and should not, be tolerated by airlines and their employees.

Moral issues aside, if for no other reason than the ongoing quest for ever elusive profit margins the industry must address this issue.

THE PROBLEM AREAS

Heavy Baggage

Although international convention suggests there is a 32kg limit on any one piece of baggage, very often this limit is not enforced. The result is a steady stream worldwide of bags well over the limit, some over 40 and even 50kgs.

This exacerbates an already difficult situation. The risk of injury in the manual handling tasks increases almost exponentially as the weight of baggage increases above 32kgs.

Check-in

Many airports have transfer belts to reduce the risk of manual handling injury to check-in agents. However, while these have been very successful, the risk of injury to ramp employees has increased as a result of their introduction.

The pressure of checking in large numbers of passengers usually results in more than one bag at a time being placed on the check in scales. This ensures that overweight bags are transferred to the ramp undetected.

Loading Containers and Barrows

Baggage room staff are required to lift baggage from the check-in delivery belt and stack items within containers or onto barrows. Under normal circumstances traditional manual handling lifting techniques can be used for these tasks. However, this is not always possible, and on many occasions loading realities necessitate heavy baggage being stacked above head height. Clearly employees involved in these tasks are exposed to significant injury risk.

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Narrow Body Aircraft Cargo Holds

This is probably the highest injury risk location. Staff are required to operate in confined space, with significant limitations on posture whilst pushing, pulling, lifting, and stacking baggage to maximise utilisation of the available space.

Similar injury risks exist in the unloading process as are present during loading.

In-plane Systems

In-plane container movement and locking systems minimise injury risk during loading and unloading of wide body aircraft. However when such systems are faulty or inoperative, the resultant manual handling risks to employees forced to man-handle heavy containers and pallets, often up to 4 tonnes, is astronomical.

The general level of serviceability of in-plane systems is poor. Many airlines do not regard such system failures as critical no-go malfunctions and often place low priority on rectification. This results in a large number of aircraft operating with defective in-plane systems for protracted periods.

Warped Containers and Pallets

Poor serviceability of containers and pallets also magnify the problems which exist when loading wide-bodied aircraft. Warped pallets and container bases often cause them not to slide smoothly along guides and catch on latches and locks. Also, drive rollers do not always gain positive contact with warped bases. Again, these unserviceabilities directly increase injury risk in employees forced to man-handle such faulty equipment.

SOLUTIONS

Baggage Weight and Size Limitations

There is an urgent need for the international aviation community to set baggage weight limitations based on realistic OH&S criteria rather than commercial values. At the very least, there needs to be a concerted effort to adhere to the existing 32kg limit. No passenger, however good a customer they may be, should be permitted to place staff at risk due to their non-compliance. Some airlines have introduced policies requiring passengers to re-pack their baggage at check-in to reduce single item weights below the standard. These airlines provide basic carry-alls free of charge to passengers for this purpose.

However, for this effort to achieve a long term solution, many more airlines would have to adopt the policy than do presently.

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Mechanisation of Baggage Transfer Tasks

Most transfer tasks, currently carried out by manual handling, are suitable candidates for mechanical assistance or robotics solutions. The high injury costs being experienced by the industry should make hi-tech robotics solutions cost effective.

Maintenance Systems

There is no doubt the industry needs to make wholesale improvements to baggage transfer systems maintenance. Airlines need to ensure that a similar priority is given to maintenance of loading equipment as is afforded to other aircraft systems. Pressure should be applied by all responsible airlines and handling companies to those operators who offer substandard equipment and systems.

The Role of Back Support Belts

While the scientific literature almost unanimously fails to endorse back support belts as an injury prevention tool, most airlines and other organisations who have introduced back belts to their manual handling work forces, seem to have found that the incidence of back injury has been significantly reduced following their introduction.

Unfortunately, many of these organisations have failed to report their positive experiences adequately and most information available is anecdotal. Clearly, acceptance of back belts, as a part solution to our industry's manual handling problem, would be higher if those organisations with positive outcomes formally published their findings.

STUDIES BEING UNDERTAKEN IN AUSTRALIA

Manual Handling Risk Assessment.

Latrobe University have been contracted to conduct an assessment of all manual handling tasks performed by baggage handlers. Video footage of postures, baggage weights and dimensions, and work rate data is being collected for analysis using the University of Michigan computerised 3 dimensional model. This study will provide quantification of the various manual handling risks so that resources can be targeted toward the areas of greatest exposure.

The "Tolai" Back Support Harness

A study to determine the suitability of the "Tolai" harness has been commissioned with University of South Australia. The major study will involve 100 subjects wearing the harness for all manual handling tasks for a one year period. Subjects will be required to complete regular questionnaires concerning their physical and emotional well-being and epidemiological injury data will be gathered. In addition, a smaller sample of subjects will be routinely measured for muscle tension and flexion. The data collected from the experimental group will be compared with similar data

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from a representative control group. If the study proves positive, there will obviously be an onus on the organisation to provide harnesses for all baggage handlers. However, monitoring would need to be an ongoing process to ensure there are no adverse long term effects of harness use.

Long Term Engineering Solutions

An investigative study has been commenced through the University of Ballarat. Robotics and other mechanical technology, to assist or remove entirely, the existing manual handling tasks mentioned above, will be explored

I will ensure that the findings of each of these studies are published upon completion of the research.

CONCLUSIONS

The consistently high back injury rates in many airlines clearly indicates that the traditional manual handling lifting training, behaviour control and procedural reliance, have failed as injury control strategies.

The airline industry can not afford to continue outlays for back injury compensation at the present level. Airline OH&S Professionals must take the initiative to seek long term solutions. Many high risk areas, such as narrow-bodied cargo holds, remain unresolved due to the difficulty of finding a solution, but they must be reassessed and solutions found.

There is no doubt that the labour force is becoming impatient. Airline downsizing and economic uncertainty has resulted in an older, smaller work force being required to handle an ever increasing number of passenger bags as passenger numbers steadily grow. The circumstances will no doubt result in a steadily increasing injury rate and associated costs until adequate control measures are incorporated.

If our profession cannot achieve a satisfactory solution, there is no doubt the labour force will take action industrially to limit the permissible weight of baggage items to satisfy normal manual handling weight limit criteria under occupational health and safety legislation. Such a limit would probably reduce the baggage weight standard to 20 kg or below. This would create a significant volumetric penalty on airlines by virtually doubling the number of baggage items carried by passengers.

We can no longer accept that there is no solution to this problem in our industry. Airline OH&S Professionals must renew their efforts or risk vocational irrelevance.

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APPENDIX NO. 2:

LIST OF PRESENTATIONS AND PUBLISHED PAPERS

PAPER/PRESENTATION TITLE	CONFERENCE OR JOURNAL	DATE
"Back Injuries On The Ramp: Our Prevention Obligations"	Presentation: ARTEX Conference in **Memphis, Tennessee, USA**	May 1994
	Presentation: VIOSH, University Of Ballarat	August 1994
	Presentation: Australasian Aviation Ground Safety Council/Fiji Air Terminal Services Ramp Safety Workshop in **Nadi, Fiji**	December 1994
	Presentation: Boeing Design Engineers Meeting **Seattle, Washington, USA**	February 1995
	Presentation: McDonnell Douglas Design Engineers Meeting, **Long Beach, California, USA**	February 1995
	Presentation: Airbus Industrie, Cargo Systems Meeting in **Toulouse, France**	May 1995
	Presentation: BAe AVRO, Interiors Design Engineers Meeting, **Woodford, Cheshire, England**	June 1995
	Presentation: Fokker, Airport Compatability Specialists Meeting **Amsterdam, Holland**[47]	September 1995
"Airline Baggage Handler Back Injuries: Causes And	Presentation: University Of Ballarat, Post	February 1994

[47] Presentation conducted via video teleconference from Melbourne

PAPER/PRESENTATION TITLE	CONFERENCE OR JOURNAL	DATE
Prevention"	Graduate Conference	
	Presentation: ARTEX Ergonomics Sub-Committee Meeting, **Brussels, Belgium**	May 1995
"Baggage Handler Back Injuries: A Project Update"	Presentation: ARTEX Conference, **Sydney, Australia**	January 1996
"Baggage Handler Back Injuries: Survey Of Safety Professionals"	Presentation: ARTEX Conference **Calgary, Canada**	June 1996
"The Causes And Prevention Of Baggage Handler Back Injuries: A Survey Of Airline Safety Professionals"	**Journal Article – Peer Reviewed** Safety Science Monitor, Vol. 1 No. 3, http://www.monash.edu.au/muarc/IPSO/vol1/issue3/ab3.htm	September 1997
"Airline Baggage Handler Back Injuries: A Survey Of Baggage Handler Opinion On Causes And Prevention"	Presentation: ARTEX Conference **Mexico City, Mexico**	February 1998
	Presentation: ARTEX Conference **Seattle, USA**	June 1998
	Journal Article – Peer Reviewed Safety Science Monitor, Vol. 2 No. 2, http://www.monash.edu.au/muarc/IPSO/vol2/issue2/ab6.htm.	December 1998
"The Causes And Prevention Of Baggage Handler Back Injuries"	Presentation: Safety In Action 1998 Conference, Safety Institute of Australia, , **Melbourne, Australia**	February 1998
"Survey Of Airline Baggage Handlers Suggests Methods To Prevent Back Injuries"	**Journal Article – Refereed** Airport Operations Journal, Volume 24 No. 5, Flight Safety Foundation, Washington DC	October 1998

PAPER/PRESENTATION TITLE	CONFERENCE OR JOURNAL	DATE
"Airline Baggage Handler Back Injuries: Manual Handling Nightmare & Ergonomic Neglect"	Presentation: National Safety Council of America, 1999 Annual Congress, **New Orleans, Louisiana, USA**	October 1999
	Presentation: Australasian Aviation Ground Safety Council, 2000 Conference, **Perth, Australia**	March 2000.
	Presentation: Safety In Action 2000 Conference, Safety Institute of Australia, **Melbourne, Australia**	April 2000.
"The Causes and Prevention of Baggage Handler Back Injuries: A summary of the Literature"	Presentation: Human Factors and Ergonomic Society of Australia, Victoria Branch Melbourne Australia	February 2004

APPENDIX NO. 3:

QUESTIONNAIRE: Survey of Airline and Ground Handling Company Safety Managers

AIRLINE BAGGAGE HANDLER BACK INJURIES:
CAUSES AND PREVENTION
(An ARTEX, AAOSC and University of Ballarat Study)
SURVEY OF AIRLINE AND GROUND HANDLING COMPANY SAFETY MANAGERS

Back injuries to baggage handlers result in considerable losses to the aviation industry every year. Some companies consistently have significant numbers of baggage handlers absent due to these injuries at any time. Many of the injuries are debilitating, result in long term suffering and sometimes cause a permanent reduction in the quality of life. The aim of this survey is to gather data regarding the magnitude of the back injury problem, and to consolidate the views of Safety Managers regarding the causes and prevention of back injuries.

Question 1

How many people were employed as baggage handlers in your organisation in each of the following years?

1992........................ | 1993........................ | 1994........................

Question 2

In your organisation, what was the baggage handlers' average hours worked per week per employee?

1992........................ | 1993........................ | 1994........................

Question 3

How many baggage handler lost time back injuries were reported in your organisation in each of the following years?

1992........................ | 1993........................ | 1994........................

Question 4

What was the cost of baggage handler lost time back injuries in your organisation in each of the following years? (Cost should include cost of worker compensation, medical and rehabilitation costs).

1992 $US........................ | 1993 $US........................ | 1994 $US........................

Question 5

Rank the following workplaces in order from where most back injuries occur to where the least occur, in your experience. (1=most injuries 5=least injuries)

a) Baggage Check-in .... | b)Baggage Make-up Room .... | c) Inside Narrow Body Aircraft.....

d) Inside Wide Body Aircraft Bulk Hold .... | e) Outside Aircraft on the Ramp . ...

Question 6

Do baggage handlers in your company have to lift baggage and cargo weighing over 32Kg (70lb)? Yes/No

Question 7

Are baggage and cargo items over 32 kg (70lb) a significant injury risk to baggage handlers? Yes/No
If Yes, what do you believe the industry can do to address this issue? ....
....
....
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Question 8

From the following list of baggage handling tasks, check off five (5) that are *most* likely to cause back injuries, in your experience.

a) Lifting baggage on and off scales or conveyor at check-in	....
b) Loading baggage onto trailers in the baggage room	....
c) Loading containers in the baggage room	....
d) Unloading baggage trailers in the baggage room	....
e) Unloading containers in the baggage room	....
f) Pushing and pulling loaded baggage trailers, containers and pallet dollies	....
g) Transfering baggage from a trailer to a mobile belt positioned at an aircraft cargo door	....
h) Transfering baggage from a trailer directly into a narrow body aircraft through the cargo door	....
i) Pushing baggage from the doorway into the baggage compartment of a narrow body aircraft	....
j) Stacking baggage inside the baggage compartment of narrow body aircraft	....
k) Pushing and pulling containers and pallets inside wide body aircraft (when equipment is broken etc.)	....
l) Stacking baggage in the bulk hold of wide body aircraft	....

Question 9

What back injury control measures have you applied within your organisation?

a) Back Support Belts Yes/No If yes, what types?..
....
....
....
....

When back belts were introduced, what effect did they have on:

Number of back injuries:(circle) None / or reduced by 10% 20% 30% 40% 50% or more (specify).........

Cost of back injuries: (circle) None / or reduced by 10% 20% 30% 40% 50% or more (specify)..........

b) Back Care Training Yes/No If yes,describe the training...
....
....
....
....
....

3

When back care training was introduced, what effect did it have on:

Number of back injuries:(circle) None / or reduced by 10% 20% 30% 40% 50% or more (specify).........

Cost of back injuries: (circle) None / or reduced by 10% 20% 30% 40% 50% or more (specify)..........

c) Ground Equipment Yes/No If yes, describe the ground equipment...

When ground equipment was introduced, what effect did it have on:

Number of back injuries:(circle) None / or reduced by 10% 20% 30% 40% 50% or more (specify).........

Cost of back injuries: (circle) None / or reduced by 10% 20% 30% 40% 50% or more (specify)..........

Size of workforce: (circle) None / or reduced by 10% 20% 30% 40% 50% or more (specify)...........

d) Baggage Room Re-design Yes/No If yes, describe the design changes..

When the baggage room was re-designed, what effect did it have on:

Number of back injuries:(circle) None / or reduced by 10% 20% 30% 40% 50% or more (specify).........

Cost of back injuries: (circle) None / or reduced by 10% 20% 30% 40% 50% or more (specify)..........

Size of workforce: (circle) None / or reduced by 10% 20% 30% 40% 50% or more (specify)...........

e) Narrow Body Aircraft In-plane Baggage Stacking/Transfer System. Yes/No If yes, describe the system:

When the in-plane system was introduced, what effect did it have on:

Number of back injuries:(circle) None / or reduced by 10% 20% 30% 40% 50% or more (specify).........

Cost of back injuries: (circle) None / or reduced by 10% 20% 30% 40% 50% or more (specify)..........

Size of workforce: (circle) None / or reduced by 10% 20% 30% 40% 50% or more (specify)...........

Question 10

In future, what measures do you believe will effectively reduce the instance of baggage handler back injuries and why?

....
....
....
....
....
....
....
....
....
....
....

Question 11

What type of aircraft does your organisation operate/handle? Insert the number of each aircraft type in your fleet:

B727	B737	B747	B757	B767	B777 ....
A300	A310	A320	A330	A340	BAe146 ....
MD11	DC10	MD80	DC9	DC8	L1011 ....
F28	Commuter......	Others (specify)	....	....	....

Question 12

How many aircraft departures did your organisation operate/handle in the following years?

1992........................	1993........................	1994........................

Question 13 - Respondent Information

All information provided will be de-identified before use. However, to allow us to clarify any details, or if respondents would like feedback on the outcome of this research, please take time to complete this section. Copies of the research outcomes will be provided to all respondents who provide their contact details.

NAME...TITLE...
ORGANISATION...
ADDRESS...
....

RESPONSES BY JULY 31, 1995 ARE REQUESTED. COMPLETED SURVEYS SHOULD BE FORWARDED IN THE ATTACHED ENVELOPE TO:

Geoff Dell M App Sci (OH&S), Grad Dip OHM, FSIA, MISASI
Victorian Institute of Occupational Safety and Health,
University of Ballarat,
PO Box 674,
Melton 3337 Australia.

THANK YOU FOR YOUR CO-OPERATION AND ASSISTANCE.

APPENDIX NO. 4:

QUESTIONNAIRE: Survey of Airline and Ground Handling Company Baggage Handlers

AIRLINE BAGGAGE HANDLER BACK INJURIES: CAUSES AND PREVENTION

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Back injuries to baggage handlers result in considerable losses to the aviation industry every year. Some companies consistently have significant numbers of baggage handlers absent due to these injuries at any time. Many of the injuries are debilitating, result in long term suffering and sometimes cause a permanent reduction in the quality of life. The aim of this survey is to gather data regarding the magnitude of the back injury problem, and to consolidate the views of baggage handlers regarding the causes and prevention of back injuries.

Try to answer all the questions. Don't think too long, we are interested in your spontaneus reactions to the questions!

1

For how many years have you worked as an airline baggage handler? ....years.

2

What age were you at your last birthday? ....years

3

Are you male or female? Male ◯ Female ◯

4

Rank the following workplaces in order from where most back injuries occur to where the least occur, in your experience. (1=most injuries 5=least injuries)

Baggage Check-in ◯

Baggage Make-up Room ◯

Inside Narrow Body Aircroft ◯

Inside Wide Body Aircraft Bulk Hold ◯

Outside Aircraft on the Ramp ◯

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5

Do baggage handlers in your company have to lift baggage and cargo weighing over 32Kg (70lb)?

○ Yes ○ No

6

Are baggage and cargo items over 32 kg (70lb) a significant injury risk , in your opinion?

○ Yes ○ No

If Yes, which of the following measures do you believe the industry should adopt to reduce the injury risk?

a) Introduce and enforce a lower limit on passenger's baggage and cargo?

○ Yes ○ No

b) Educate the public about the injury risks caused by heavy baggage?

○ Yes ○ No

c) Introduce better procedures for the acceptance of baggage and cargo?

○ Yes ○ No

d) Provide mechanical assistance devices for lifting heavy baggage?

○ Yes ○ No

e) Make passengers re-pack heavy baggage into smaller/lighter containers before check-in?

○ Yes ○ No

f) Put "Heavy" tags on all heavy items to warn baggage handlers of the increased risk when lifting?

○ Yes ○ No

g) Introduce better baggage handler training?

○ Yes ○ No

AIRLINE BAGGAGE HANDLER BACK INJURIES: CAUSES AND PREVENTION

SURVEY OF AIRLINE AND GROUND HANDLING COMPANY BAGGAGE HANDLERS

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h) Other?
Please
specify...
....
....
....
....
....
....
....
....
....
....

7

Grade the following baggage handling tasks from Unlikely (0) to Most Likely (10), to cause back injuries, in your experience.

	Unlikely	**Most likely**
a) Lifting baggage on and off scales or conveyor at check-in	0|--|--|--|--|--|--|--|--|--|--|10	
b) Loading baggage onto trailers in the baggage room	0|--|--|--|--|--|--|--|--|--|--|10	
c) Loading containers in the baggage room	0|--|--|--|--|--|--|--|--|--|--|10	
d) Unloading baggage trailers in the baggage room	0|--|--|--|--|--|--|--|--|--|--|10	
e) Unloading containers in the baggage room	0|--|--|--|--|--|--|--|--|--|--|10	
f) Pushing and pulling loaded baggage trailers, containers and pallet dollies	0|--|--|--|--|--|--|--|--|--|--|10	
g) Transferring baggage from a trailer to a mobile belt positioned at an aircraft cargo door	0|--|--|--|--|--|--|--|--|--|--|10	

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h) Transfering baggage from a trailer directly into a narrow body aircraft through the cargo door — 0|--|--|--|--|--|--|--|--|--|--|10

i) Pushing baggage from the doorway into the baggage compartment of a narrow body aircraft — 0|--|--|--|--|--|--|--|--|--|--|10

j) Stacking baggage inside the baggage compartment of narrow body aircraft — 0|--|--|--|--|--|--|--|--|--|--|10

k) Pushing and pulling containers and pallets inside wide body aircraft (when equipment is broken etc) — 0|--|--|--|--|--|--|--|--|--|--|10

l) Stacking baggage in the bulk hold of wide body aircraft — 0|--|--|--|--|--|--|--|--|--|--|10

8

Have you personally experienced one or more lost time back injuries while working as a baggage handler?

○ Yes ○ No

If Yes, please answer the following:

a) From the list (a to l) in Question 7 above, what task were you performing at the time of injury? (If you have had more than one injury, circle one task for each injury)

(Circle) a, b, c, d, e, f, g, h, i, j, k, l, or Other (give details):

....
....
....
....
....
....
....

b) Has the injury reduced your ability to carry out baggage handling tasks?

○ Yes ○ No

AIRLINE BAGGAGE HANDLER BACK INJURIES: CAUSES AND PREVENTION

SURVEY OF AIRLINE AND GROUND HANDLING COMPANY BAGGAGE HANDLERS

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If Yes, describe your specific problem or disability;..
....
....
....
....
....
....
....
....
....
....
....

c) How many years ago did your back injury occur?

Years: Less than 1 ◯ 1 ◯ 2 ◯ 3 ◯ 4 ◯

5 ◯ 6 ◯ 7 ◯ 8 ◯ 9 ◯ 10 ◯

11 ◯ 12 ◯ 13 ◯ 14 ◯ 15 ◯ More than 15 ◯

d) Has the same injury recurred since?

◯ Yes ◯ No

If yes, how many times? (circle)

1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯ 6 or more ◯

e) What has been the total number of days you have been off work due to the back injury you described above? (Don't include lost time from any other injuries you may have had)

..........Days

AIRLINE BAGGAGE HANDLER BACK INJURIES: CAUSES AND PREVENTION

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f) How often do you experience back pain?

Several Times Daily ◯ Once a Day ◯

Several Times a Week ◯ Once a week ◯

Several Times a Month ◯ Once a Month ◯

Seldom ◯

9

a) In the past, has your organisation used BACK SUPPORT BELTS as a back injury prevention measure?

Yes ◯ No ◯

If yes, what type? Rigid weight lifters belt ◯

Elastic lumbar support belt ◯

b) Have you personally worn a back support belt to help prevent back injuries?

Yes ◯ No ◯

If yes, what type? Rigid weight lifters belt ◯

Elastic lumbar support belt ◯

c) Have you experienced a lost time back injury while wearing a back support belt?

Yes ◯ No ◯

d) Give your opinion of the following statements:

(i) **"Back support belts improve the wearer's ability to carry out baggage handling tasks".**

Strongly Agree ◯ Agree ◯ Disagree ◯ Strongly Disagree ◯

(ii) **"A back support belt will help prevent lost time back injuries".**

Strongly Agree ◯ Agree ◯ Disagree ◯ Strongly Disagree ◯

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(iii) **"Back support belts should be worn for all lifting tasks".**

Strongly Agree ◯ Agree ◯ Disagree ◯ Strongly Disagree ◯

(iv) **"Back support belts make lifting technique training unnecessary".**

Strongly Agree ◯ Agree ◯ Disagree ◯ Strongly Disagree ◯

(v) **"Back care training is unnecessary when back support belts are used".**

Strongly Agree ◯ Agree ◯ Disagree ◯ Strongly Disagree ◯

(vi) **"If you wear a back support belt for lifting at work, you must wear one for lifting at home".**

Strongly Agree ◯ Agree ◯ Disagree ◯ Strongly Disagree ◯

10

In the past, has your organisation provided BACK CARE TRAINING as a back injury prevention measure?

Yes ◯ No ◯

If yes, what type of training was provided?

Proper lifting technique (back straight, knees bent etc) training	Yes ◯	No ◯
Physical fitness training	Yes ◯	No ◯
Lifting with resticted postures in confined spaces	Yes ◯	No ◯
Back physiology and musculoskeletal function	Yes ◯	No ◯
The need for warm up exercises before lifting at work	Yes ◯	No ◯

AIRLINE BAGGAGE HANDLER BACK INJURIES: CAUSES AND PREVENTION

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11

Give your opinion on the following statements:

(i) **"Back care training improves baggage handlers' ability to carry out baggage handling tasks".**

Strongly Agree ◯ Agree ◯ Disagree ◯ Strongly Disagree ◯

(ii) **"Back care training will help prevent lost time back injuries".**

Strongly Agree ◯ Agree ◯ Disagree ◯ Strongly Disagree ◯

(iii) **"Lifting technique (back straight, knees bent etc) training is of no benefit to baggage handlers".**

Strongly Agree ◯ Agree ◯ Disagree ◯ Strongly Disagree ◯

(iv) **"Training should be provided that includes techniques for lifting with resticted postures in confined spaces".**

Strongly Agree ◯ Agree ◯ Disagree ◯ Strongly Disagree ◯

(v) **"Warm up exercises should form a part of the daily routine of baggage handlers".**

Strongly Agree ◯ Agree ◯ Disagree ◯ Strongly Disagree ◯

AIRLINE BAGGAGE HANDLER BACK INJURIES: CAUSES AND PREVENTION

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12

a) Has your organisation introduced any of the following GROUND EQUIPMENT to reduce risk of baggage handler back injuries?

Mobile conveyor belts	Yes ◯	No ◯
Pneumatic lifting aids	Yes ◯	No ◯
Robotic lifting devices	Yes ◯	No ◯
Forklift pallets with rollers	Yes ◯	No ◯

Other
(describe)..
....
....
....
....
....
....

b) In your opinion, has the ground equipment made the baggage handling tasks easier, harder or had no effect:

Mobile conveyor belts	Easier ◯	Harder ◯	No Effect ◯
Mechanical lifting aids	Easier ◯	Harder ◯	No Effect ◯
Forklift pallets with rollers	Easier ◯	Harder ◯	No Effect ◯
Others (describe)			
....	Easier ◯	Harder ◯	No Effect ◯
....	Easier ◯	Harder ◯	No Effect ◯
....	Easier ◯	Harder ◯	No Effect ◯

AIRLINE BAGGAGE HANDLER BACK INJURIES: CAUSES AND PREVENTION

SURVEY OF AIRLINE AND GROUND HANDLING COMPANY BAGGAGE HANDLERS

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c) Do you believe the ground equipment provided helps reduce back injuries?

Mobile conveyor belts	Yes	◯	No	◯
Mechanical lifting aids	Yes	◯	No	◯
Forklift pallets with rollers	Yes	◯	No	◯

Others (describe)

....	Yes	◯	No	◯
....	Yes	◯	No	◯
....	Yes	◯	No	◯

13

Give your opinion on the following statements:

a) **"In general, Baggage Sorting Rooms are designed to make the job of baggage handlers easier".**

Strongly Agree ◯ Agree ◯ Disagree ◯ Strongly Disagree ◯

b) **"The heights of converyor belts in baggage rooms meet the needs of baggage handlers".**

Strongly Agree ◯ Agree ◯ Disagree ◯ Strongly Disagree ◯

c) **"It is easier to load baggage into wide body baggage containers than onto narrow body baggage trailers".**

Strongly Agree ◯ Agree ◯ Disagree ◯ Strongly Disagree ◯

d) **"Wide body baggage containers reduce the risk of baggage handler back injuries".**

Strongly Agree ◯ Agree ◯ Disagree ◯ Strongly Disagree ◯

14

a) Has your organisation introduced NARROW BODY AIRCRAFT IN-PLANE BAGGAGE STACKING SYSTEMS.

Yes ◯ No ◯

If yes, which system? Scandinavian Sliding Carpet ◯

American Ace Nesting System ◯

Other (Describe the system)

....

....

....

b) In your opinion, has the system made the baggage handling tasks:

Easier ◯

Harder ◯

No Effect ◯

c) Do you believe the system helps reduce back injuries?

Yes ◯ No ◯

d) Do you prefer to load narrow body aircraft fitted with or without an in-plane stacking system.

With ◯ Without ◯

AIRLINE BAGGAGE HANDLER BACK INJURIES: CAUSES AND PREVENTION

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e) Have you ever experienced a lost time back injury while loading a narrow body aircraft fitted with an in-plane stacking system.

Yes ◯ No ◯

15

In future, which of the following measures do you believe will effectively reduce the instance of baggage handler back injuries?

a) Better Training and Education of Baggage Handlers	Yes ◯	No ◯
b) Introduce Warm-up Exercises	Yes ◯	No ◯
c) Allocate/Employ Staff to Meet Job Needs	Yes ◯	No ◯
d) Improve supervision	Yes ◯	No ◯
e) Slow the Baggage Handling Process Down	Yes ◯	No ◯
f) Introduce Back Belts	Yes ◯	No ◯
g) Limit Baggage Weights	Yes ◯	No ◯
h) Redesign Baggage Handling Systems	Yes ◯	No ◯
i) Develop In-plane Baggage/Cargo Stacking Systems	Yes ◯	No ◯
j) Introduce Robotics to Eliminate Manual Handling	Yes ◯	No ◯
k) Better Maintenance of Equipment	Yes ◯	No ◯
l)Redesign Aircraft	Yes ◯	No ◯
m)Conduct More Scientific Studies of Baggage Handling tasks	Yes ◯	No ◯
n) Others (describe)..	Yes ◯	No ◯
....	Yes ◯	No ◯
....	Yes ◯	No ◯

16
Respondent Information

All information provided will be de-identified before use. However, to allow us to clarify any details, or if respondents would like feedback on the outcome of this research, please take time to complete this section. Copies of the research outcomes will be provided to all respondents who provide their contact details.

NAME..

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ORGANISATION..

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....

....

....

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Victorian Institute of Occupational Safety and Health,
University of Ballarat,
PO Box 674,
Melton 3337 Australia.

THANK YOU FOR YOUR CO-OPERATION AND ASSISTANCE.

APPENDIX NO. 5:

AIR CARGO EQUIPMENT (ACE) ADVERTISING BROCHURE WITH INJURY REDUCTION CLAIM

WANT TO KNOW THE SECRET OF PLAYING THE FUTURES MARKET?

PORK BELLIES ARE OUT, AIRCRAFT BELLIES ARE IN!

You won't find cargo holds listed on any commodities exchange, but every aircraft has them and they're proving to be the profit center of the airline industry. The smart money knows that there is a way to dramatically increase those profits, and you don't have to wait for the future to capitalize. The **ACE TELESCOPING CARGO SYSTEM** for narrow-body aircraft is paying dividends today!

Systems Portfolio: Nine aircraft models
Industry Indicators: Operated by over 30 airlines
At Today's Closing: Over 1000 sold

ACE TELESCOPING CARGO SYSTEM RETURN ON INVESTMENT:

Up to...

- 50% reduction in cargo handling labor costs
- 75% reduction in personnel injury costs
- 75% reduction in aircraft liner damage costs
- 25% reduction in cargo damage costs
- 30% increase in loading efficiency
- 12 month ROI in most installations

For a free prospectus and Cost Benefits/Payback Analysis contact:

Air Cargo Equipment Corporation
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Rancho Dominguez, California 90221-5817
Tel: 01 310 898-2200 • Fax: 01 310 631-1954

ZERO **Air Cargo Equipment**
A ZERO Corporation Company

Air Cargo Equipment (UK) Limited
Unit 12, Space Waye
Feltham, Middlesex TW14 OTH U. K
Tel: 0181 890 0788 • Fax: 0181 844 1320

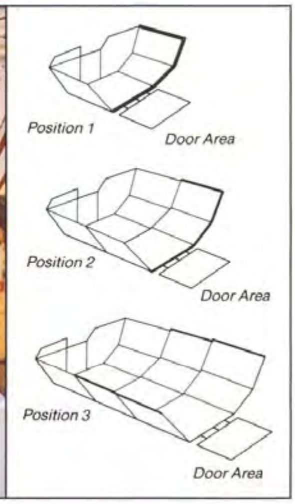
APPENDIX NO. 6:

AIR CARGO EQUIPMENT (ACE) TELESCOPING CARGO SYSTEM SPECIFICATIONS

Telescoping Cargo System
QUICK SPECS

AIRCRAFT TYPE	LOCATION	LENGTH	NUMBER OF MODULES	CERTIFICATION
Airbus A-320	FWD	113.75 in. (2.84m)	2	FAA-STC
	AFT	113.75 in. (2.84m)	2	FAA-STC
Boeing 727-200	FWD	180.0 in. (4.57m)	3	FAA-STC
Boeing 737-300	AFT	155.0 in. (3.94m)	3	FAA-STC
Boeing 737-400	AFT	203.0 in. (5.16m)	3	FAA-STC
Boeing 757-200	FWD	205.0 in. (5.22m)	3	FAA-BAC/TC
(BAC installed)	AFT	160.0 in. (4.06m)	2	FAA-BAC/TC
Boeing 757-200	FWD	203.25 in. (5.16m)	3	FAA-STC
(retrofit)	AFT	157.50 in. (4.00m)	2	FAA-STC
MDC DC-9-41	FWD	143.0 in. (3.63m)	3	FAA-STC
	AFT	167.0 in. (4.24m)	3	FAA-STC
MDC DC-9-51	FWD	143.0 in. (3.63m)	2	FAA-STC
	MID	255.0 in. (6.48m)	3	FAA-STC
	AFT	200.0 in. (5.08m)	2	FAA-STC

Notes: — Electrical required from aircraft - 115V A/C, 3 phase, 400 cycles, 2.4 amps (motor), 28V D/C (controls).
— Weights available on request.
— System can be adapted to all standard body lower baggage/cargo area.
— No major airframe modifications required - mounts to existing structure.



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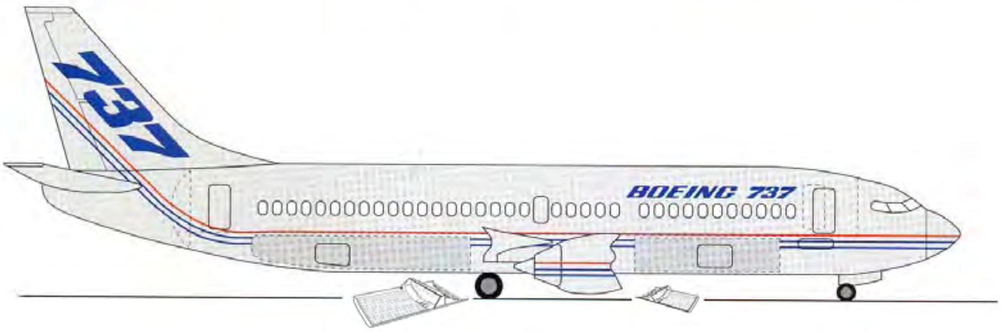
APPENDIX NO. 7:

SLIDING CARPET SYSTEM SPECIFICATIONS

Shipset configuration for 737-300/-400/-500 Aircraft



737-300:	33/10300	33/20200
737-400:	34/10300	34/20200
737-500:	35/10300	35/20200

Sliding Carpet Loading System
Length data

Loading system Part number	Length (meters)	Length (inches)
33/20200	2.2	86
34/10300	5.3	200
35/10300	3.1	123

The shipset may consist of any combination of systems according to the needs of the operator.
The above figure shows the systems available for the aircraft.
Data is provided for the longest and the shortest system.

APPENDIX NO. 8:

DETAILS OF QANTAS BAGGAGE HANDLERS WHO PARTICIPATED IN THE TRIALS AT THE UNIVERSITY OF BALLARAT

SUBJECT No.	AGE (years)	WEIGHT (kgs)	HEIGHT (cm)	BAGGAGE HANDLING EXPERIENCE (years)	AIRPORT
1	35	82.4	183	1	Sydney
2	48	80.7	176	20	Melbourne
3	47	86.0	182	9	Sydney
4	52	102.0	174	31	Sydney
5	53	71.0	173	25	Sydney
6	33	83.0	177	11	Brisbane
7	33	81.0	181	1	Sydney
8	33	81.9	179	1	Brisbane
9	47	86.0	173	24	Melbourne

APPENDIX NO. 9:
POTENTIAL CONFOUNDING VARIABLES AND CONTROLS APPLIED

Potentially Confounding Variable	Control Applied
Variations in the size and shape of the baggage	Medium sized suitcases were obtained with dimensions as consistent as possible.
Uneven distribution of weight within each item of baggage	Each bag was weighted with rags, old clothing and crumpled up newspaper in attempt to evenly distribute the weight
Variations in the weight of bags	Each bag was filled with rags, old clothing and crumpled up newspaper until it weighed 15kg gross weight
Variations in the number of bags used by subjects to fill the mock-up to the ceiling	Subjects were instructed to use the techniques they would normally adopt when loading aircraft and attempt to fill the entire space, floor to ceiling with baggage.
Differences in the rate baggage was presented to the baggage handler	Baggage was offered to the subjects at a target rate of one every six seconds
Effect of any pattern in sequence of baggage offered to subjects	Order of baggage presented to subjects was randomised
Differences between baggage handler methods, experience, training, physique, wellness, age, etc.	Each subject compared with themselves only, loading baggage across the three trial configurations. No comparison between subjects attempted

APPENDIX NO. 10:
MPEG VIDEO FREEZE FRAMES

Figure 10.1
Subject 1 Top Left

Figure 10.2
Subject 1 Top Centre

Figure 10.3
Subject 1 Top Right

Figure 10.4
Subject 2 Top Left

Figure 10.5
Subject 2 Top Centre

Figure 10.6
Subject 2 Top Right

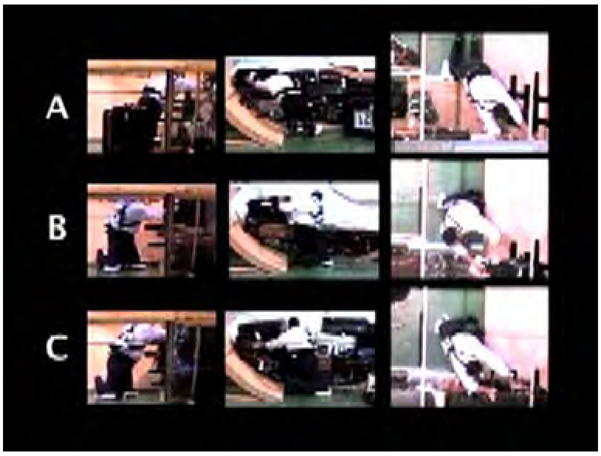


Figure 10.7
Subject 3 Top Left

Figure 10.8
Subject 3 Top Centre

Figure 10.9
Subject 3 Top Right

Figure 10.10
Subject 4 Top Left

Figure 10.11
Subject 4 Top Centre

Figure 10.12
Subject 4 Top Right

Figure 10.13
Subject 5 Top Left

Figure 10.14
Subject 5 Top Centre

Figure 10.15
Subject 5 Top Right

Figure 10.16
Subject 6 Top Left

Figure 10.17
Subject 6 Top Centre

Figure 10.18
Subject 6 Top Right

Figure 10.19
Subject 7 Top Left

Figure 10.20
Subject 7 Top Centre

Figure 10.21
Subject 7 Top Right

Figure 10.22
Subject 8 Top Left

Figure 10.23
Subject 8 Top Centre

Figure 10.24
Subject 8 Top Right

Figure 10.25
Subject 9 Top Left

Figure 10.26
Subject 9 Top Centre

Figure 10.27
Subject 9 Top Right

APPENDIX NO. 11:
POSTURES REPLICATED IN THE MICHIGAN 3D MODELLING PROGRAM

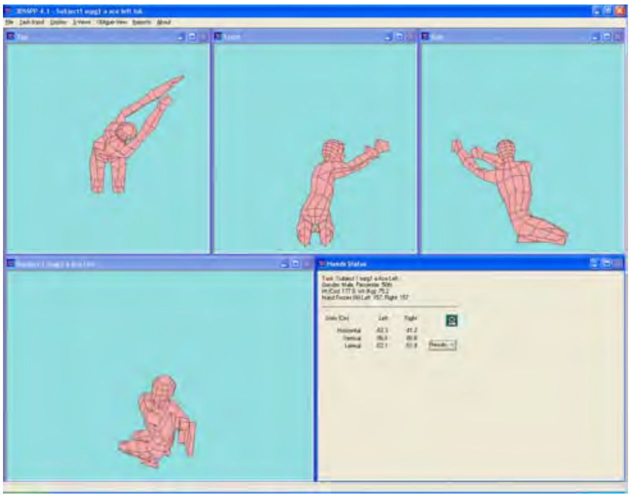


Figure A11.1
Subject 1 - Ace Left

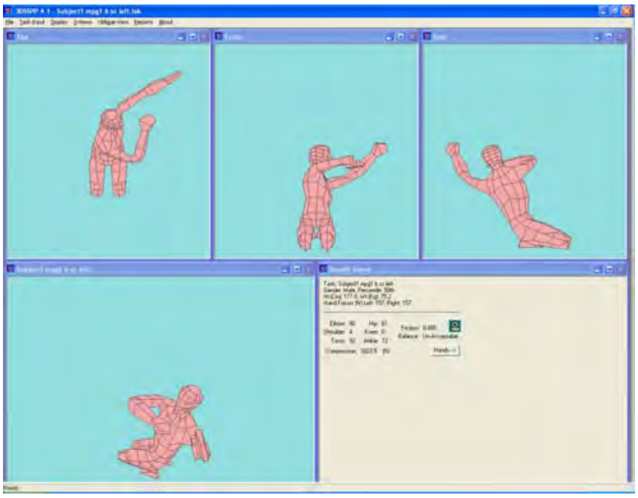


Figure A11.2
Subject 1 – Sliding Carpet Left

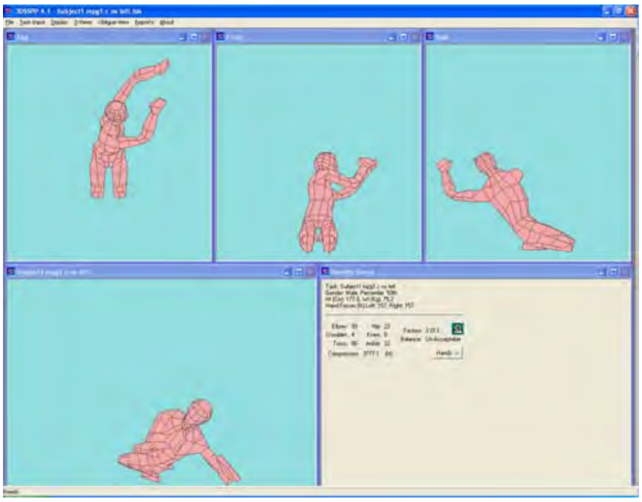


Figure A11.3
Subject 1 – No System Left

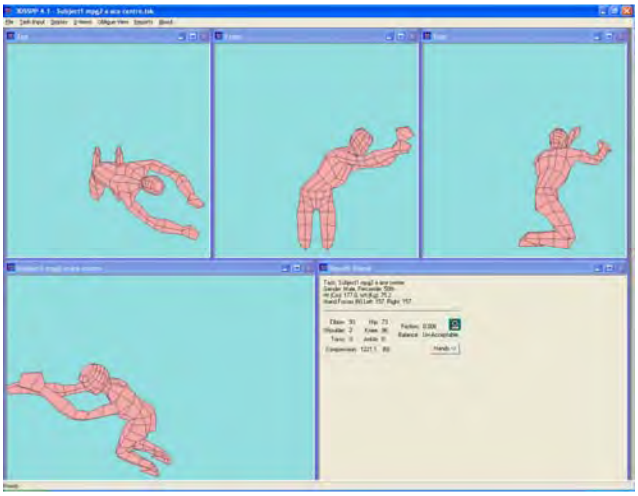


Figure A11.4
Subject 1 Ace Centre–

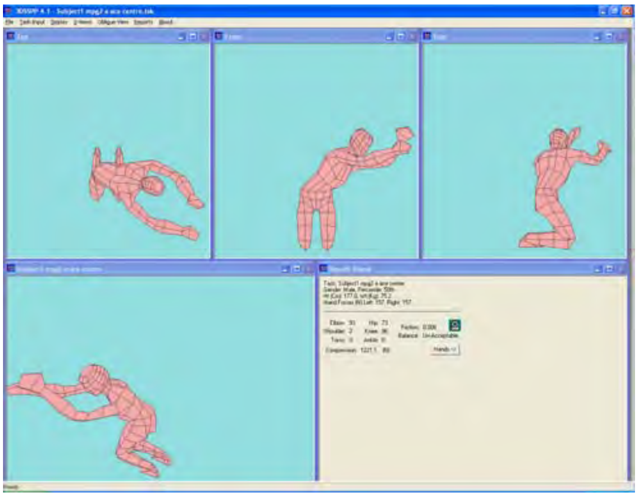


Figure A11.4
Subject 1 Ace Centre–

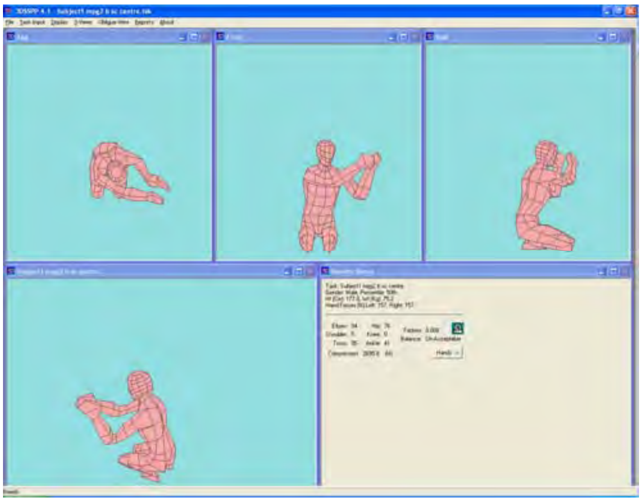


Figure A11.5
Subject 1 Sliding Carpet Centre–

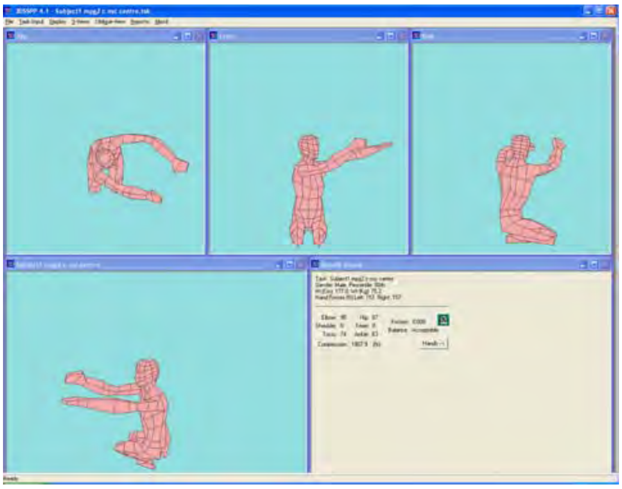


Figure A11.6
Subject 1 No System Centre–

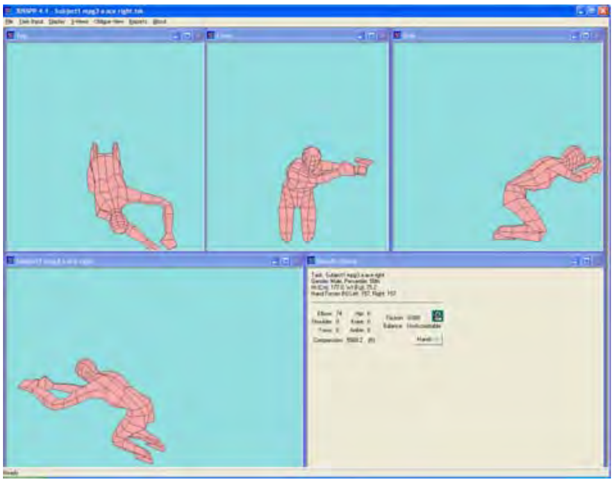


Figure A11.7
Subject 1 Ace Right–

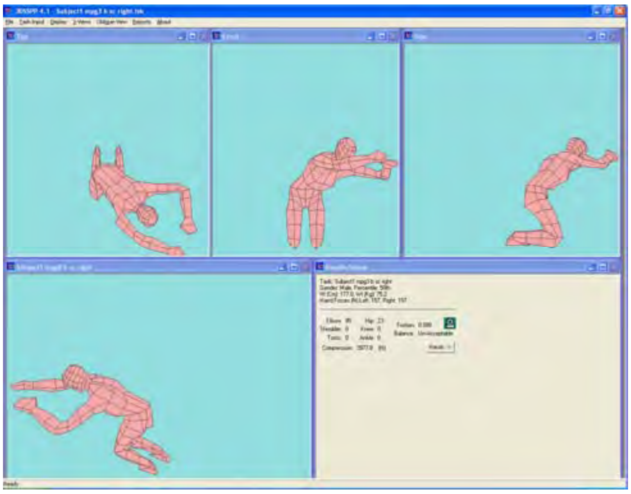


Figure A11.8
Subject 1 Sliding Carpet Right–

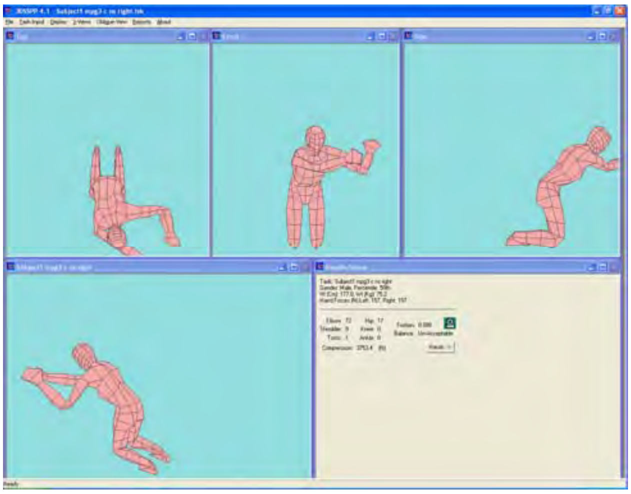


Figure A11.9
Subject 1 Sliding No System Right–

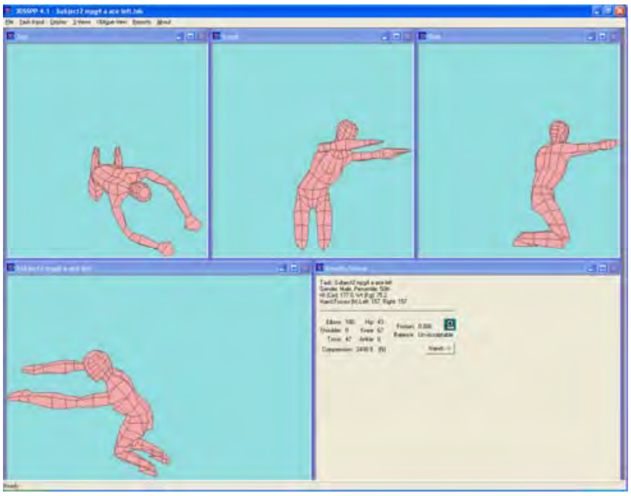


Figure A11.10
Subject 2 - Ace Left

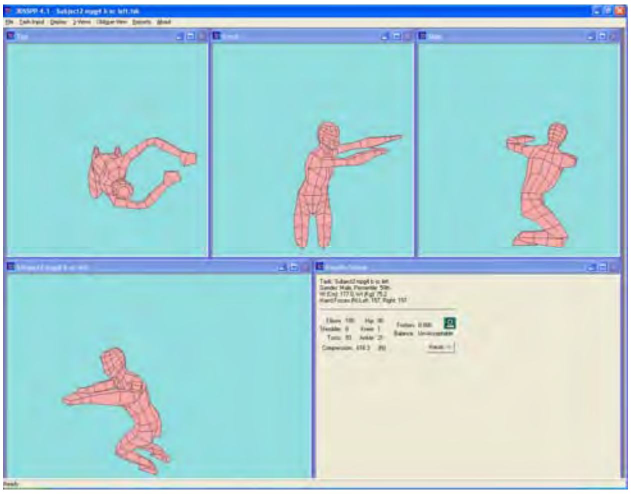


Figure A11.11
Subject 2 – Sliding Carpet Left

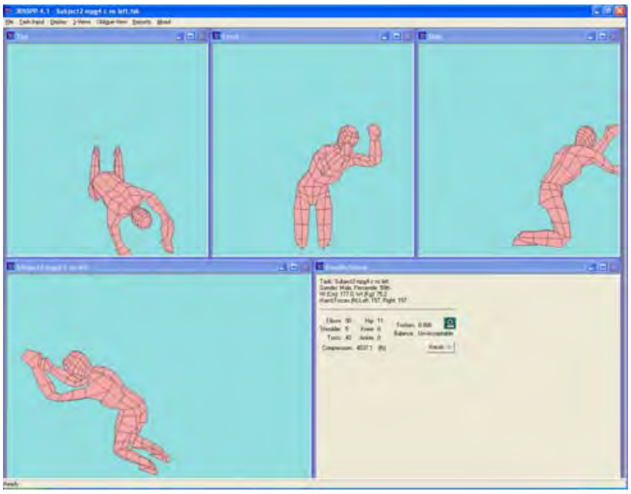


Figure A11.12
Subject 2 – No System Left

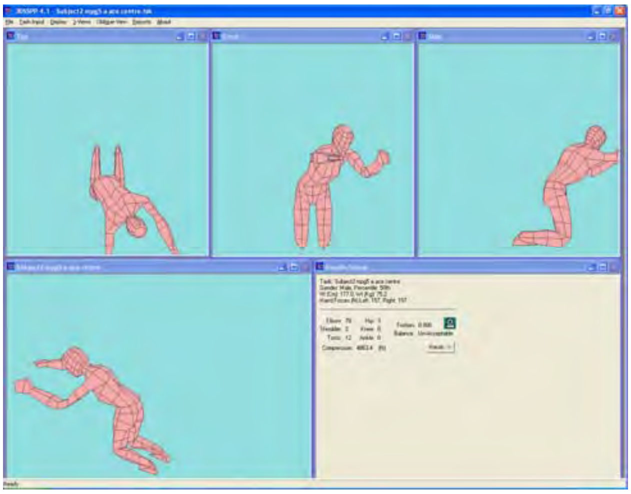


Figure A11.13
Subject 2 Ace Centre–

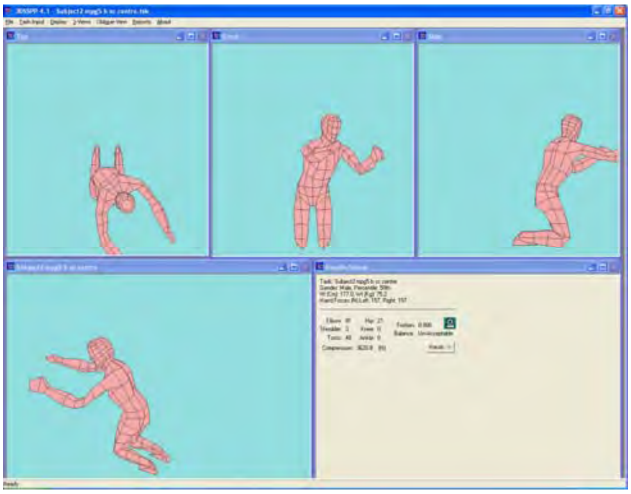


Figure A11.14
Subject 2 Sliding Carpet Centre–

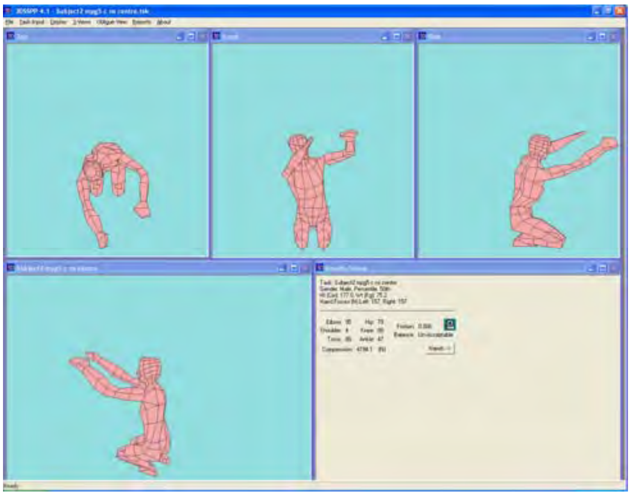


Figure A11.15
Subject 2 No System Centre

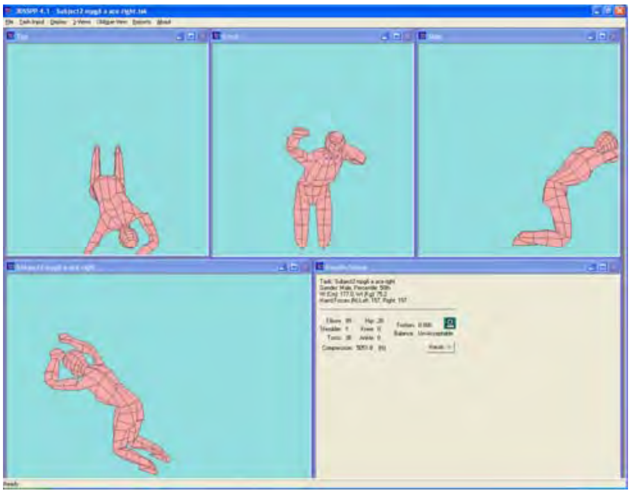


Figure A11.16
Subject 2 Ace Right–

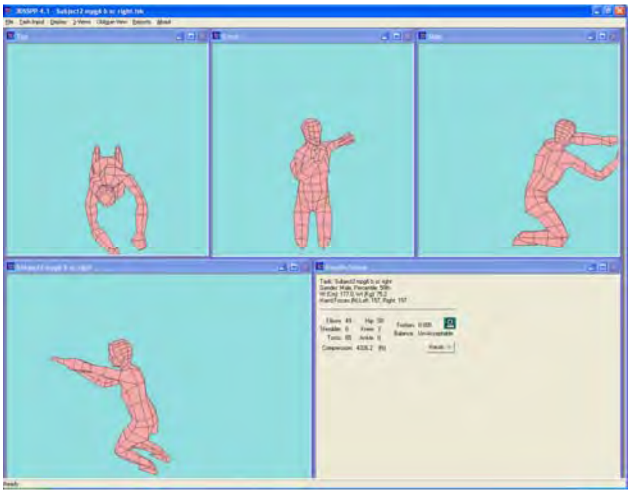


Figure A11.17
Subject 2 Sliding Carpet Right–

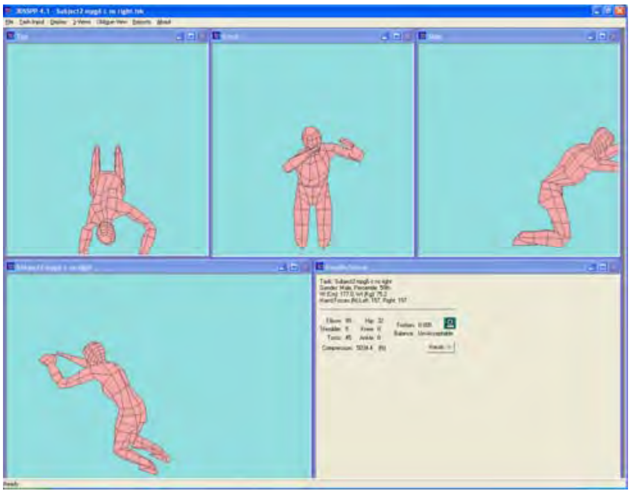


Figure A11.18
Subject 2 No System Right–

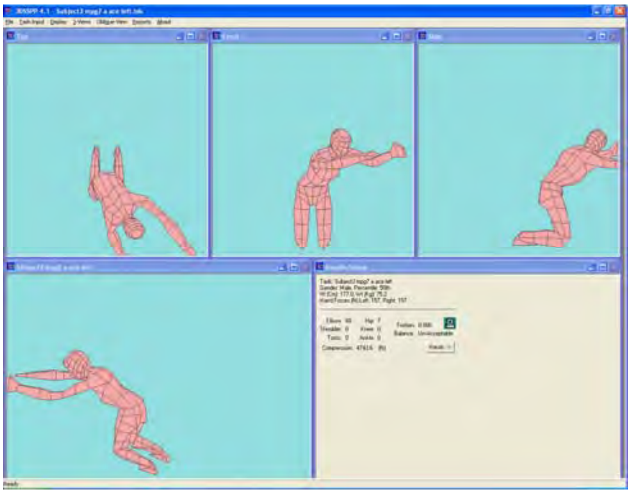


Figure A11.19
Subject 3 - Ace Left

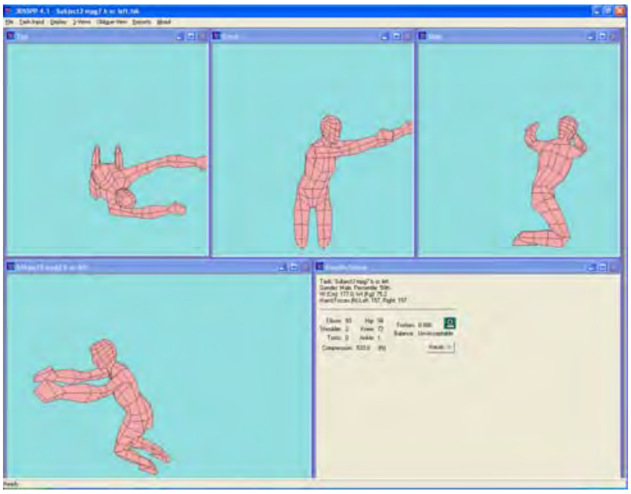


Figure A11.20
Subject 3 – Sliding Carpet Left

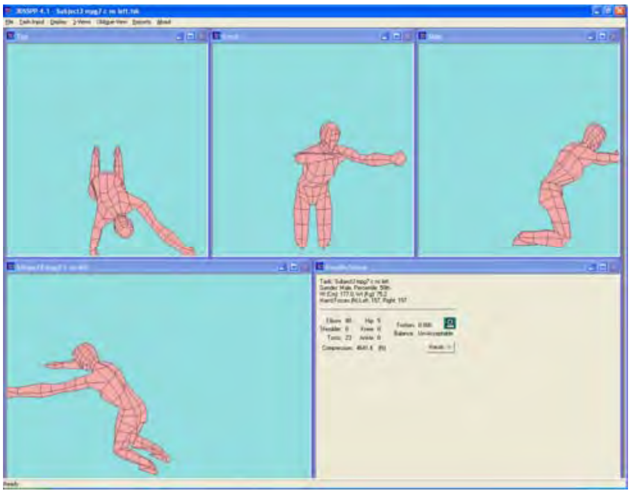


Figure A11.21
Subject 3 – No System Left

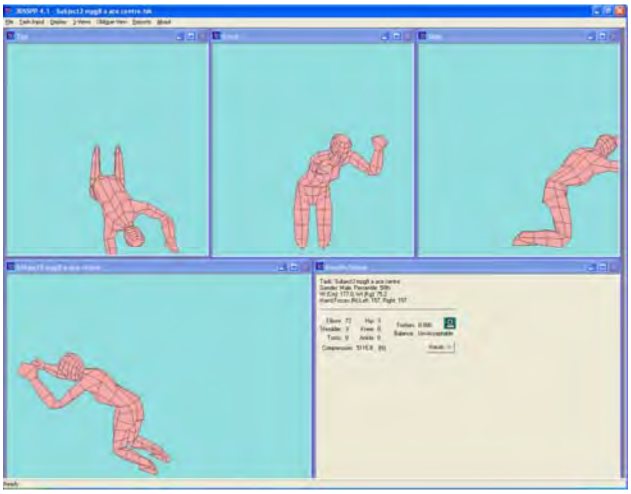


Figure A11.22
Subject 3 Ace Centre–

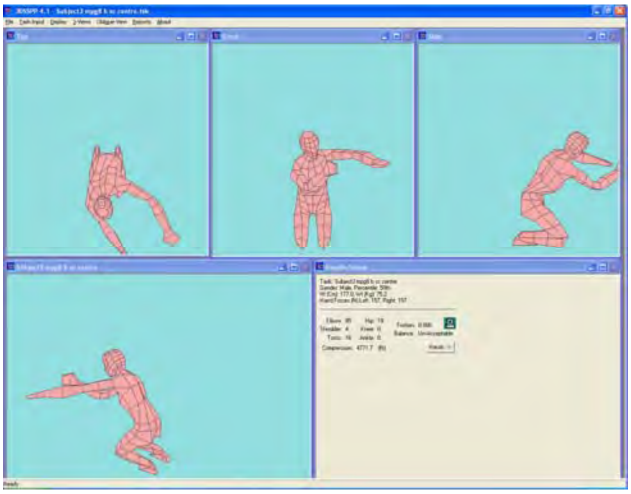


Figure A11.23
Subject 3 Sliding Carpet Centre–

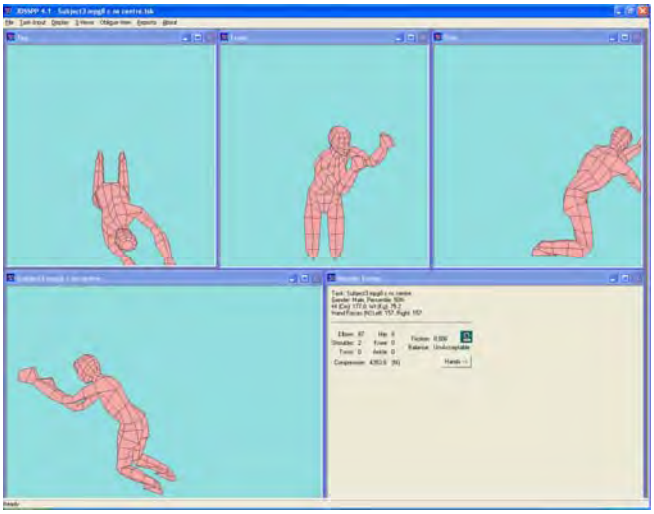


Figure A11.24
Subject 3 No System Centre–

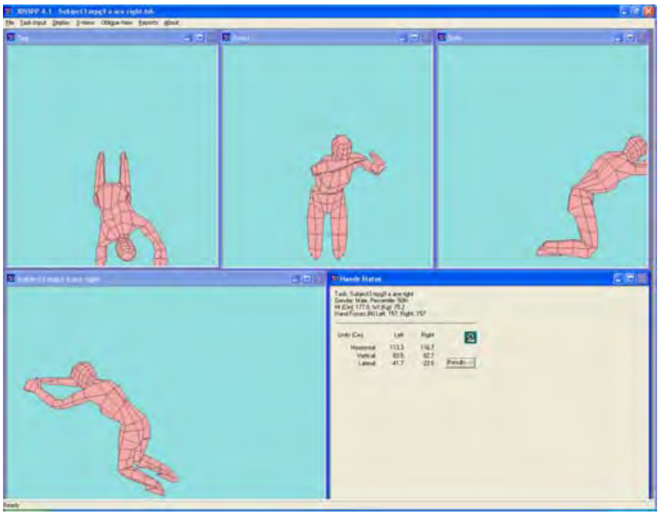


Figure A11.25
Subject 3 Ace Right–

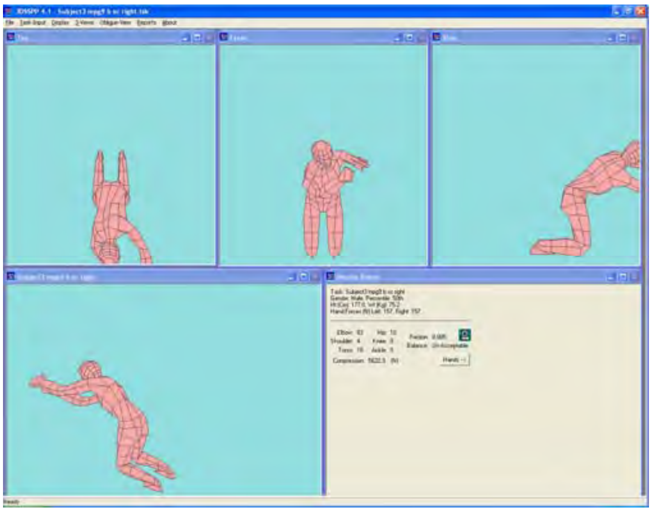


Figure A11.26
Subject 3 Sliding Carpet Right–

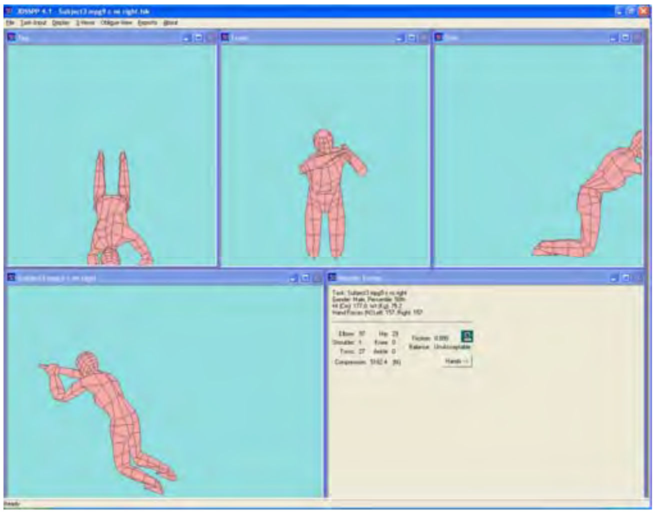


Figure A11.27
Subject 3 No System Right–

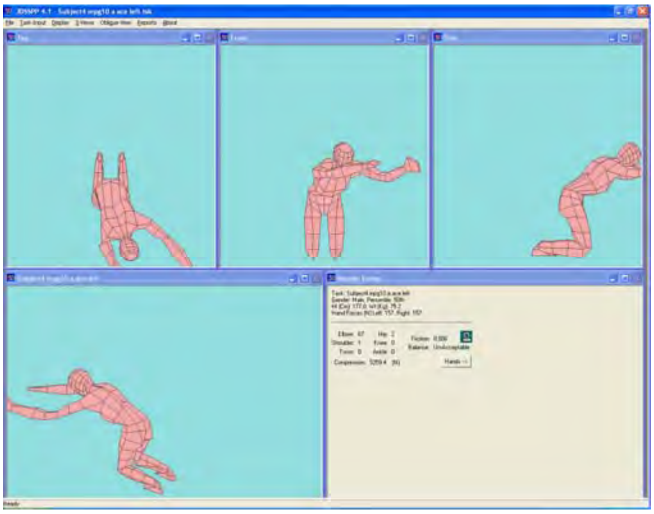


Figure A11.28
Subject 4 - Ace Left

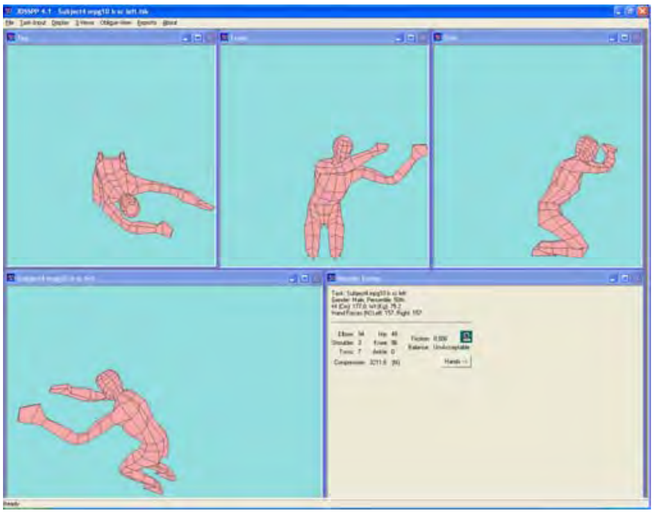


Figure A11.29
Subject 4 – Sliding Carpet Left

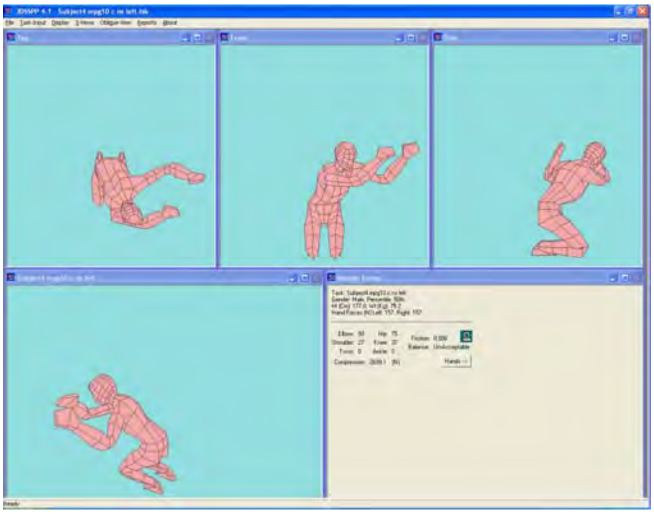


Figure A11.30
Subject 4 – No System Left

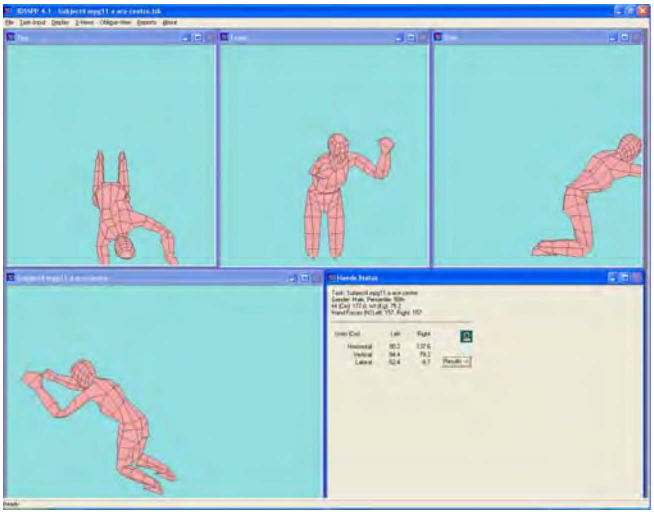


Figure A11.31
Subject 4 Ace Centre–

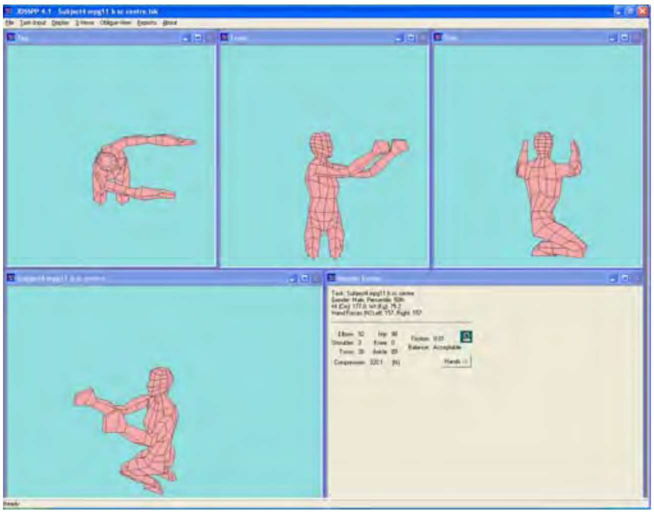


Figure A11.32
Subject 4 Sliding Carpet Centre–

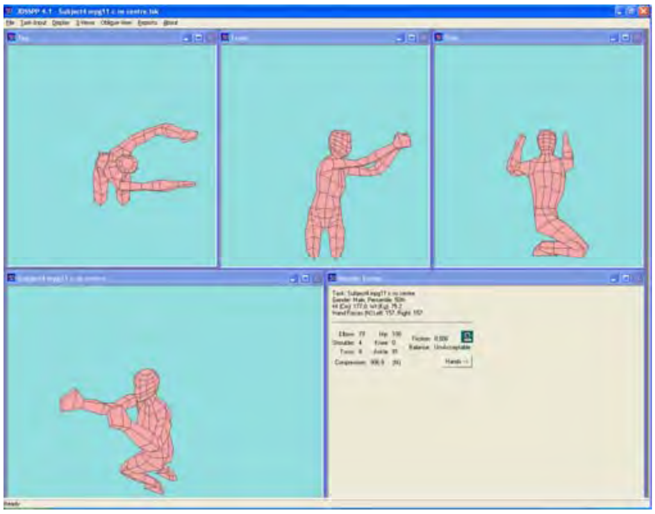


Figure A11.33
Subject 4 No System Centre

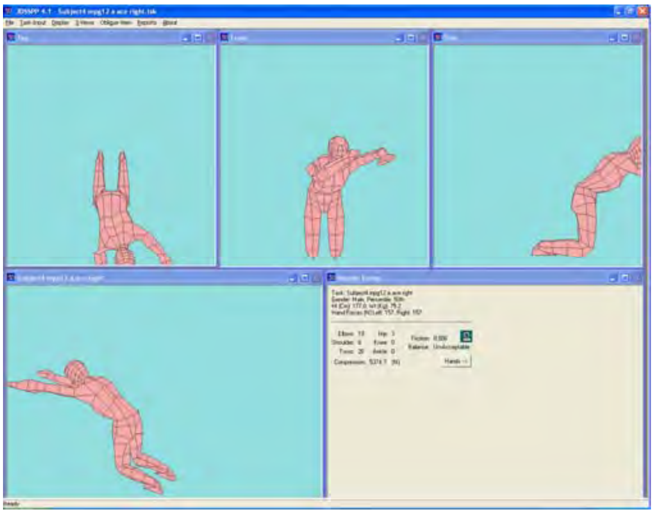


Figure A11.34
Subject 4 Ace Right–

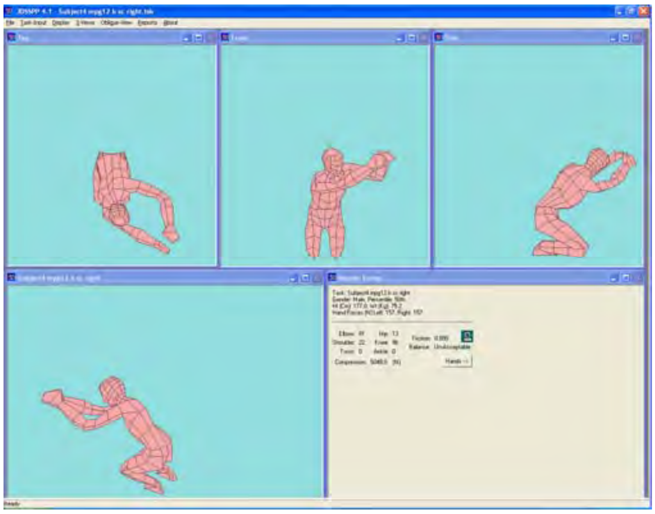


Figure A11.35
Subject 4 Sliding Carpet Right–

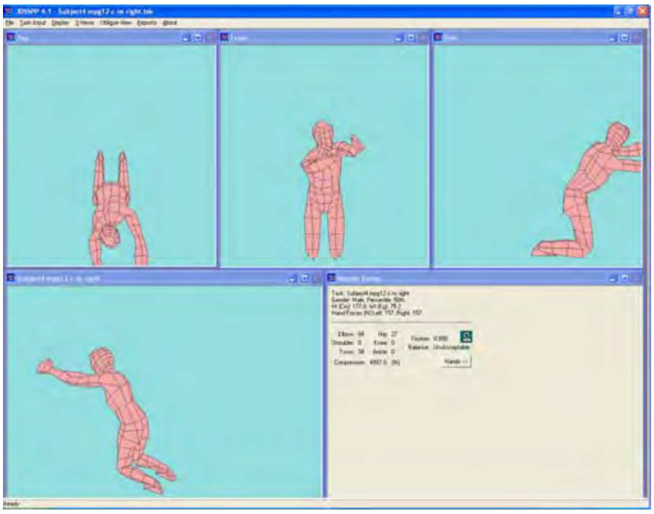


Figure A11.36
Subject 4 No System Right–

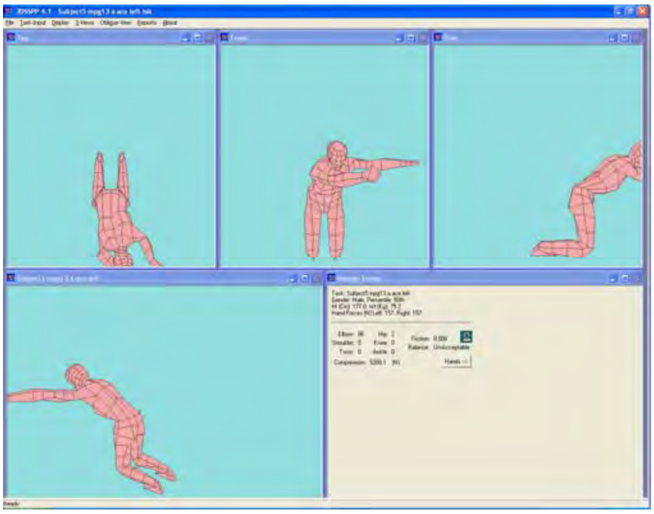


Figure A11.37
Subject 5 - Ace Left

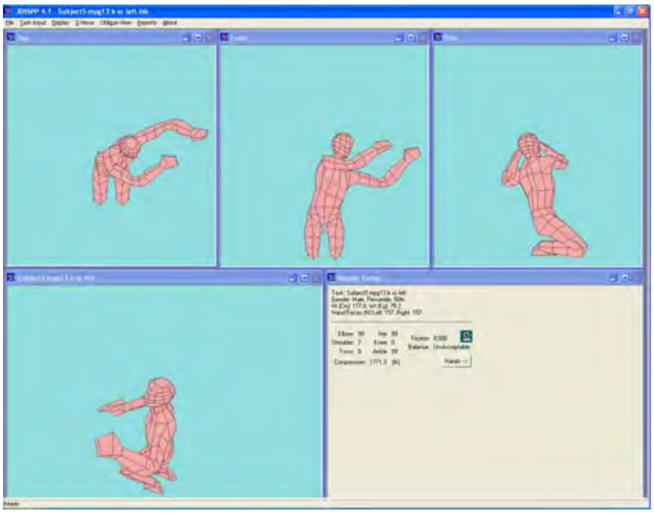


Figure A11.38
Subject 5 – Sliding Carpet Left

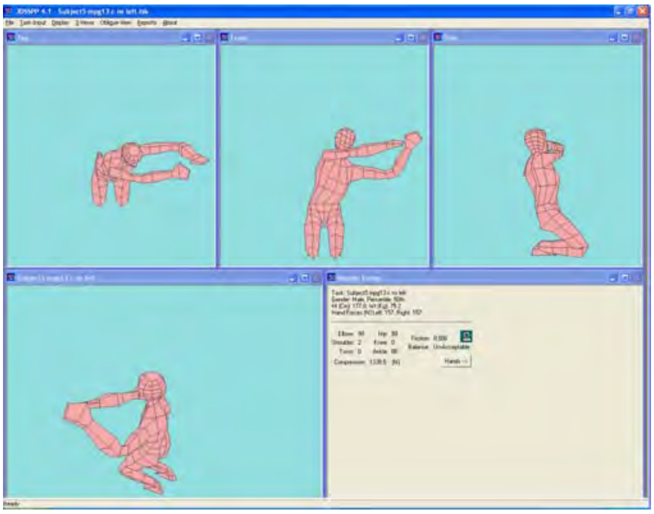


Figure A11.39
Subject 5 – No System Left

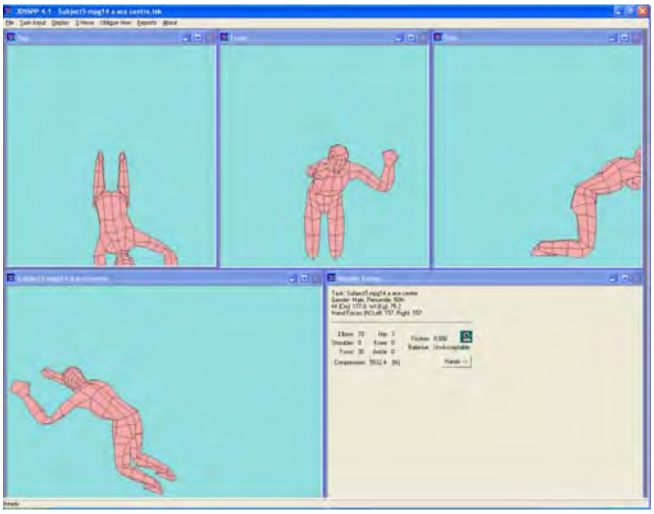


Figure A11.40
Subject 5 Ace Centre–

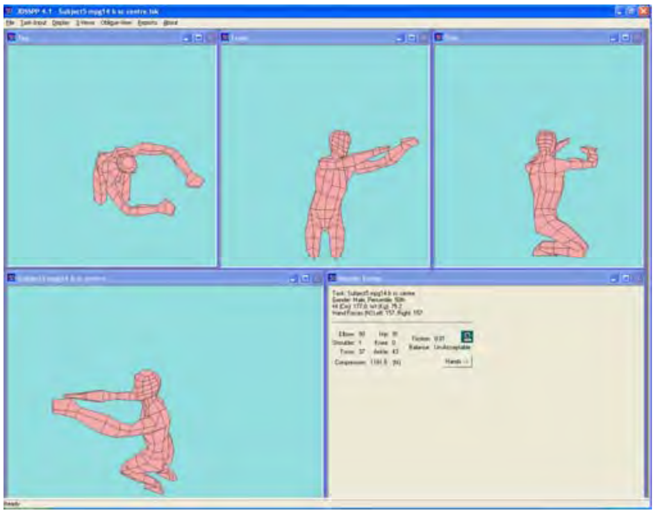


Figure A11.41
Subject 5 Sliding Carpet Centre–

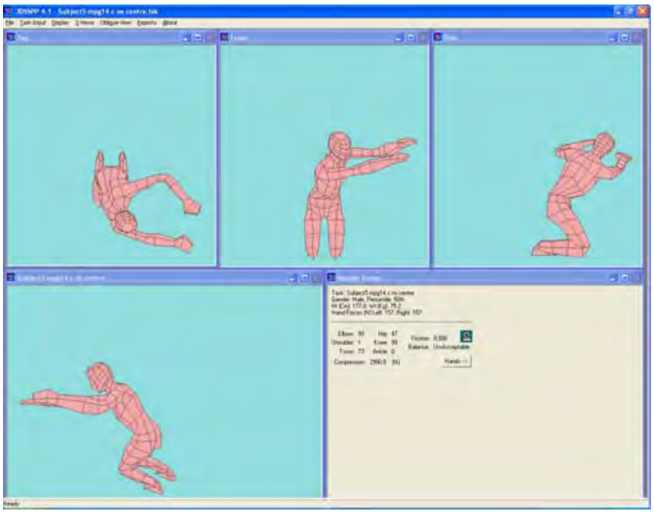


Figure A11.42
Subject 5 No System Centre–

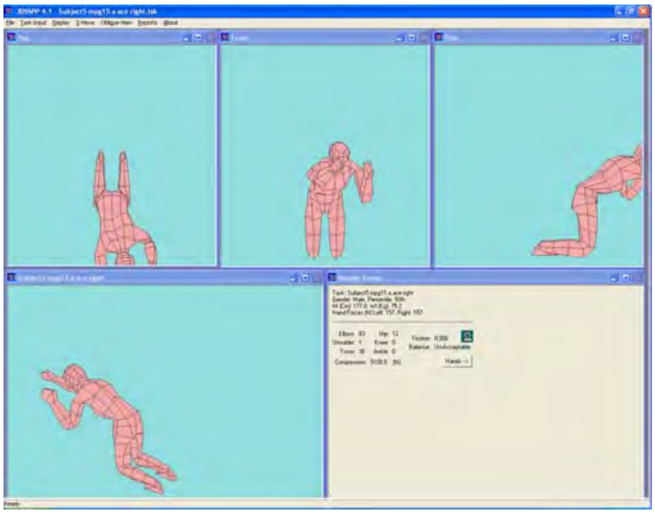


Figure A11.43
Subject 5 Ace Right–

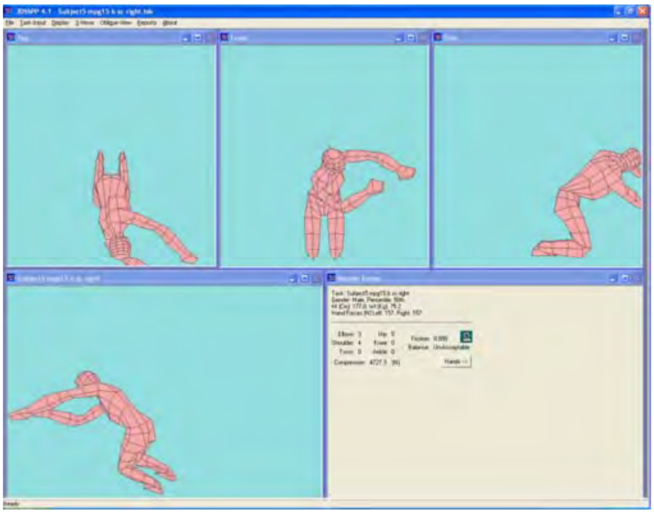


Figure A11.44
Subject 5 Sliding Carpet Right–

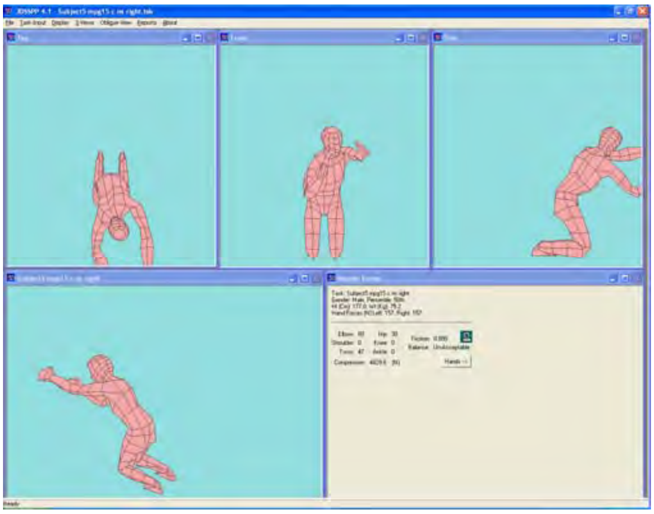


Figure A11.45
Subject 5 No System Right–

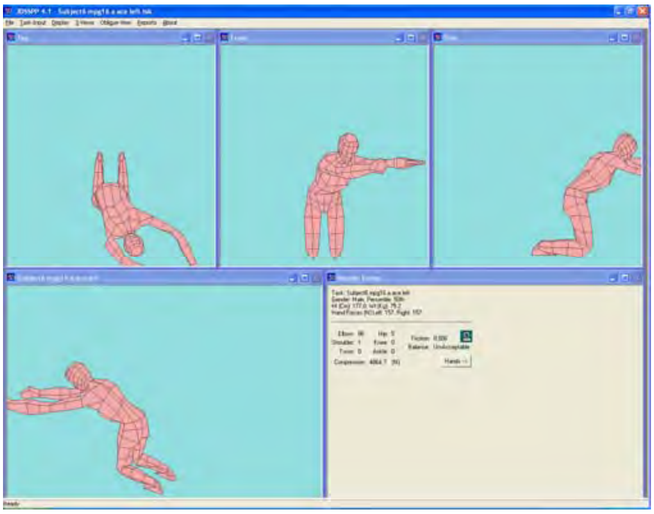


Figure A11.46
Subject 6 - Ace Left

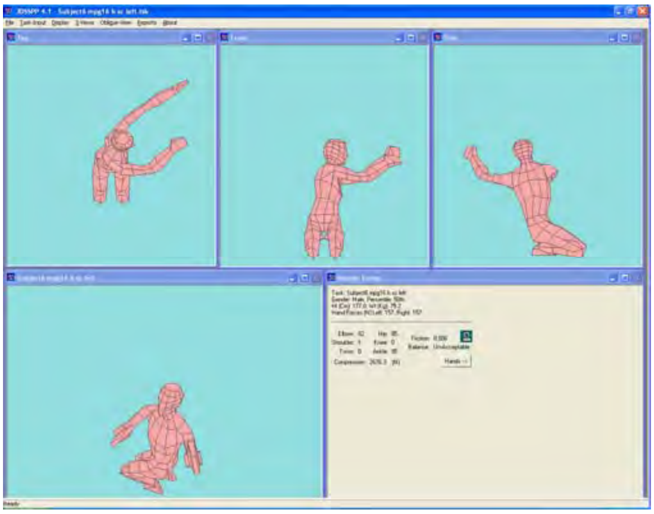


Figure A11.47
Subject 6 – Sliding Carpet Left

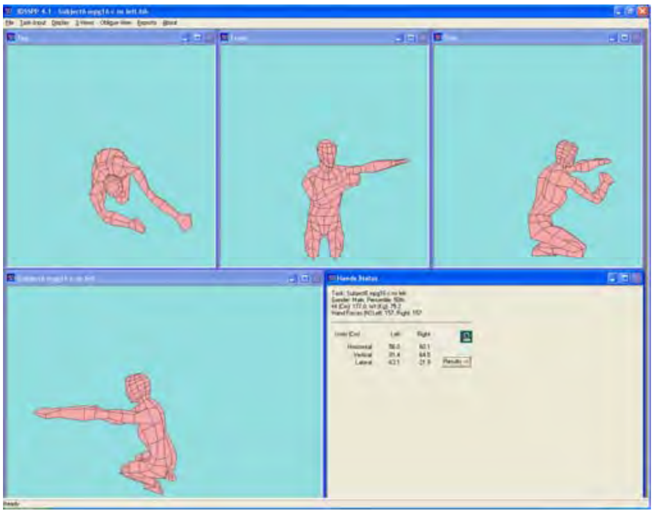


Figure A11.48
Subject 6 – No System Left

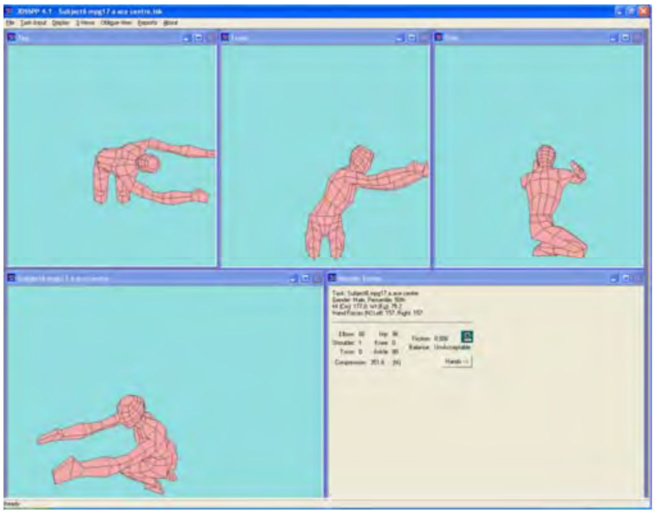


Figure A11.49
Subject 6 Ace Centre–

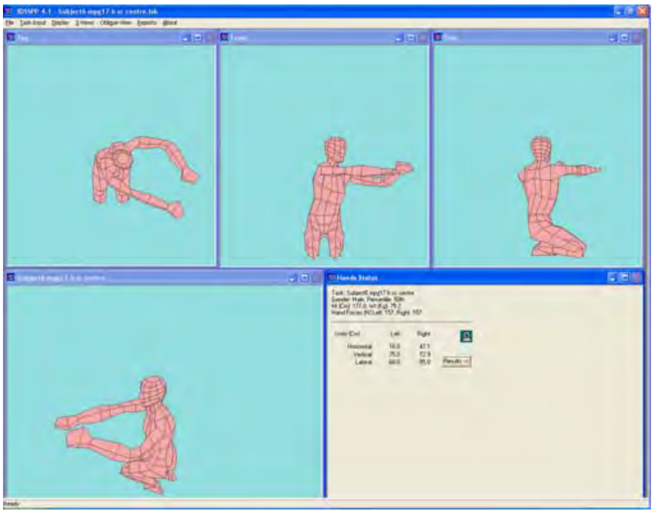


Figure A11.50
Subject 6 Sliding Carpet Centre–

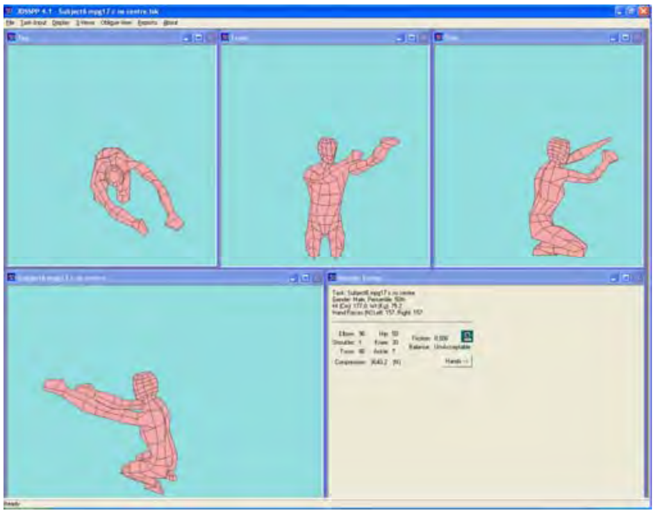


Figure A11.51
Subject 6 No System Centre–

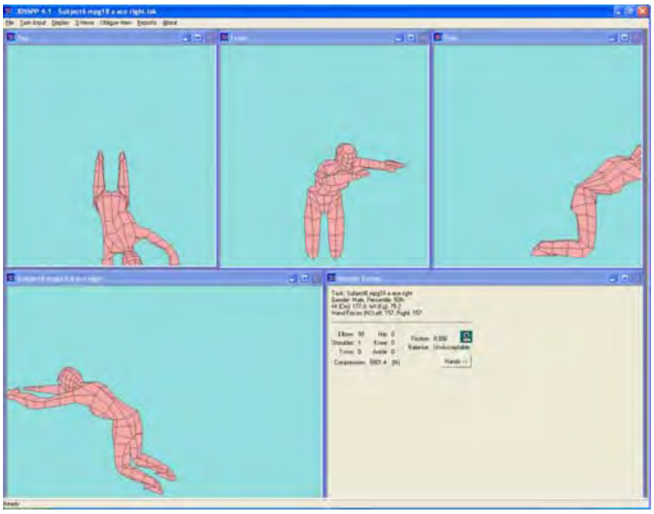


Figure A11.52
Subject 6 Ace Right–

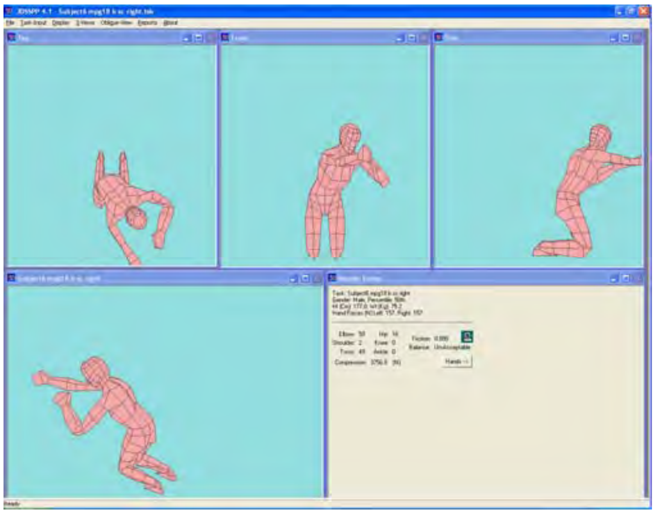


Figure A11.53
Subject 6 Sliding Carpet Right–

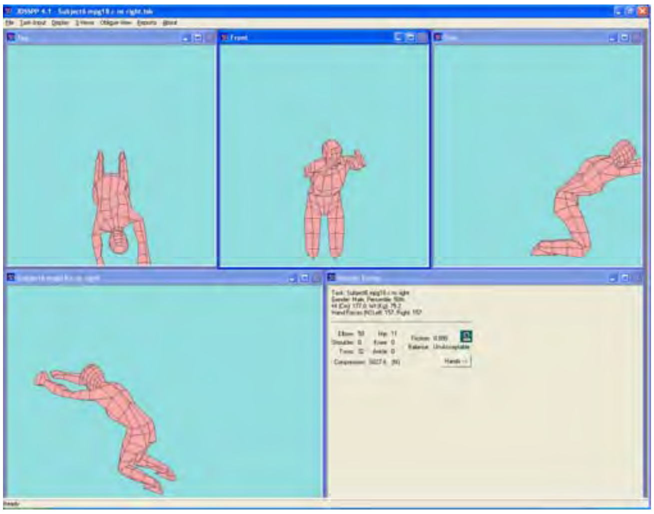


Figure A11.54
Subject 6 No System Right–

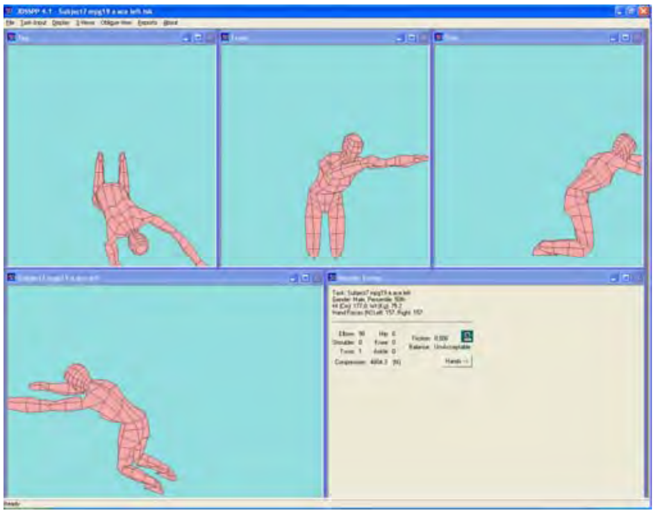


Figure A11.55
Subject 7 - Ace Left

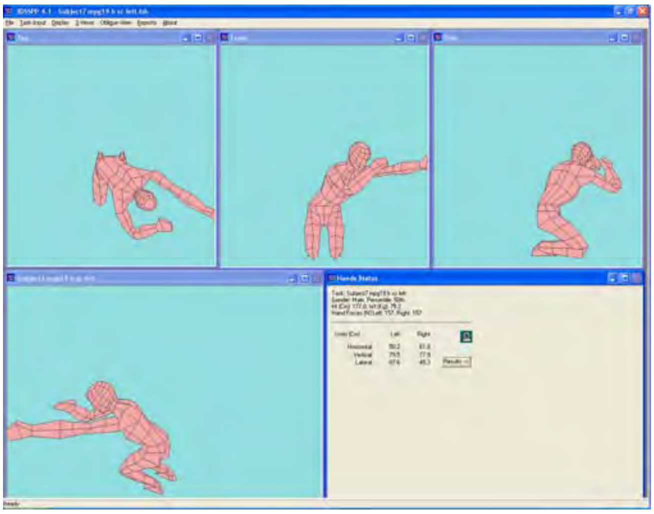


Figure A11.56
Subject 7 – Sliding Carpet Left

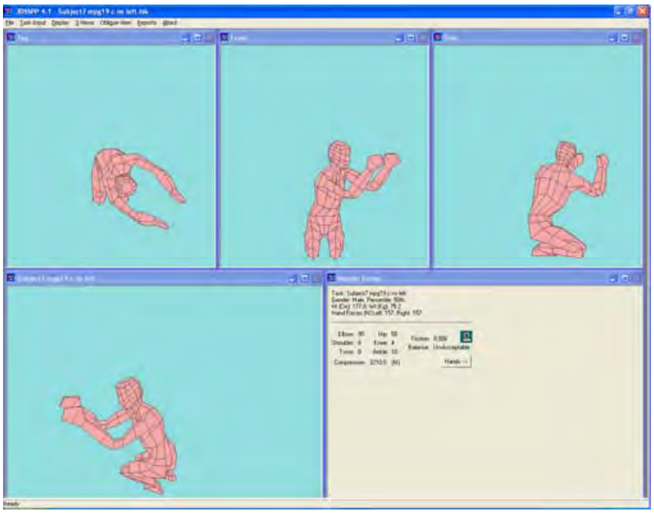


Figure A11.57
Subject 7 – No System Left

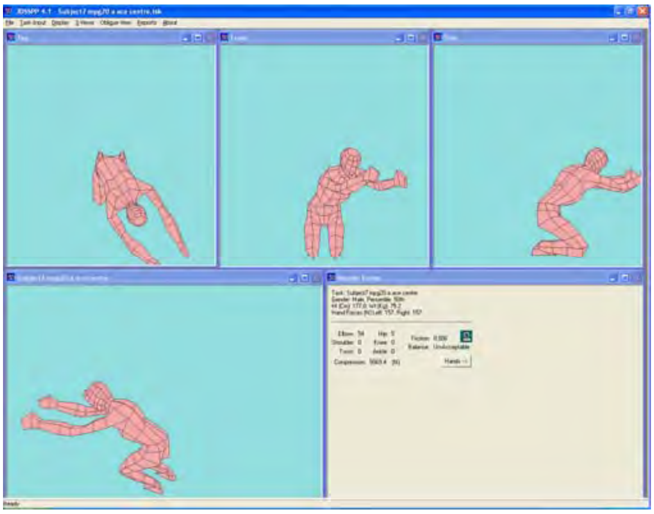


Figure A11.58
Subject 7 Ace Centre–

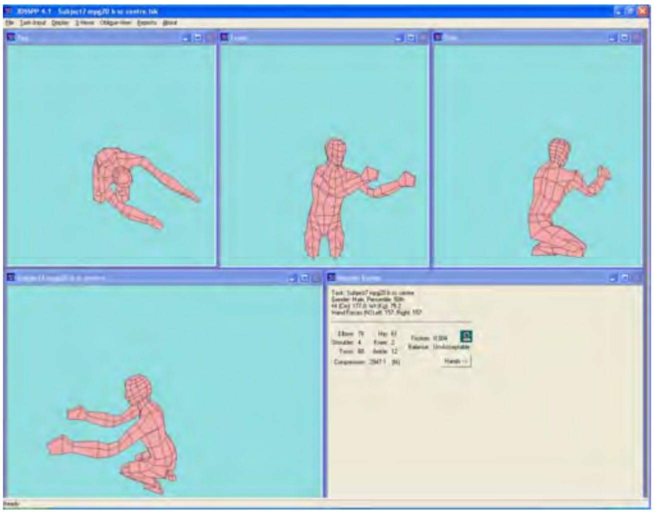


Figure A11.59
Subject 7 Sliding Carpet Centre–

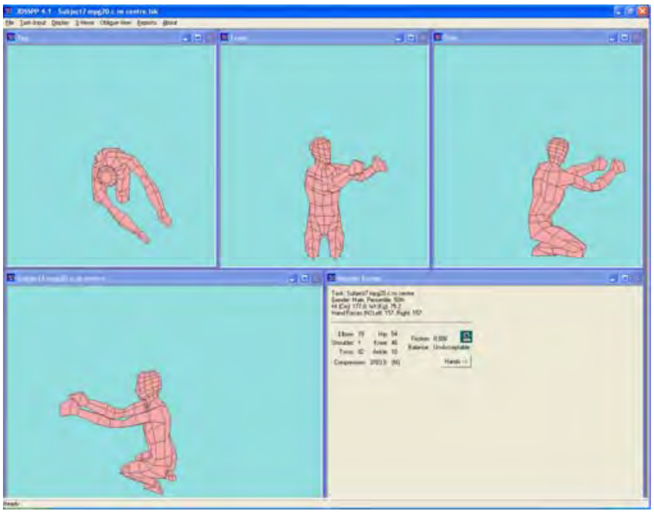


Figure A11.60
Subject 7 No System Centre–

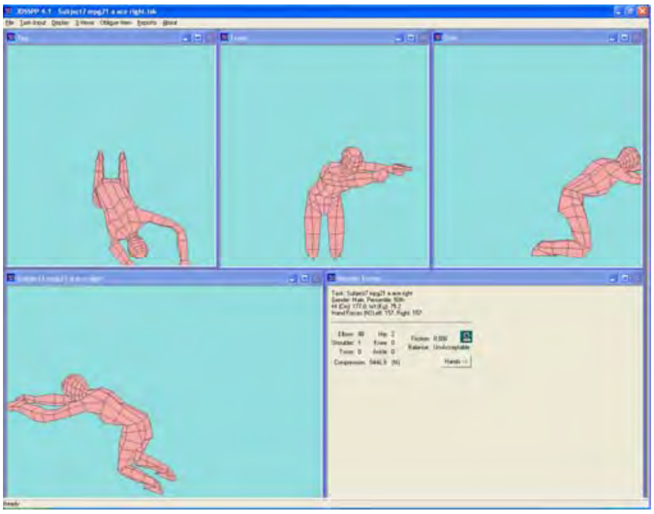


Figure A11.61
Subject 7 Ace Right–

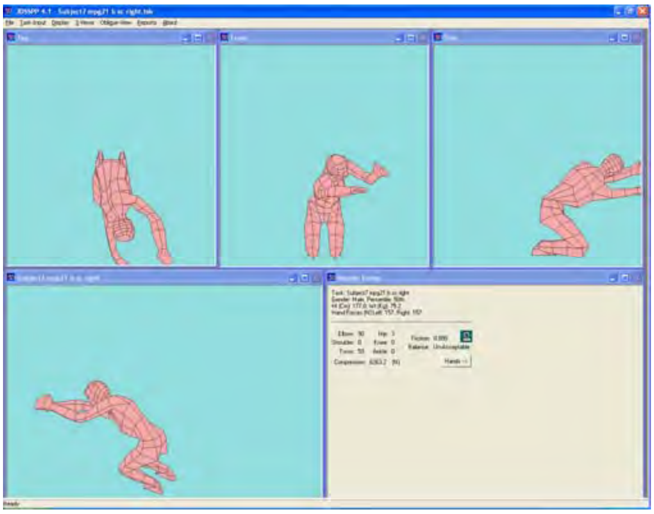


Figure A11.62
Subject 7 Sliding Carpet Right–

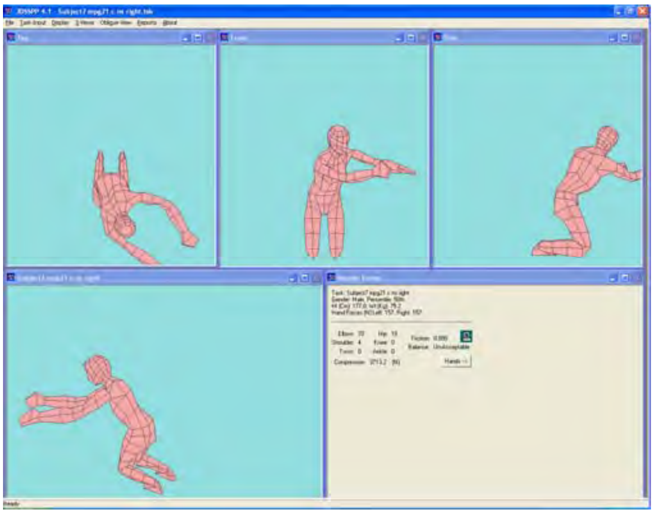


Figure A11.63
Subject 7 No System Right–

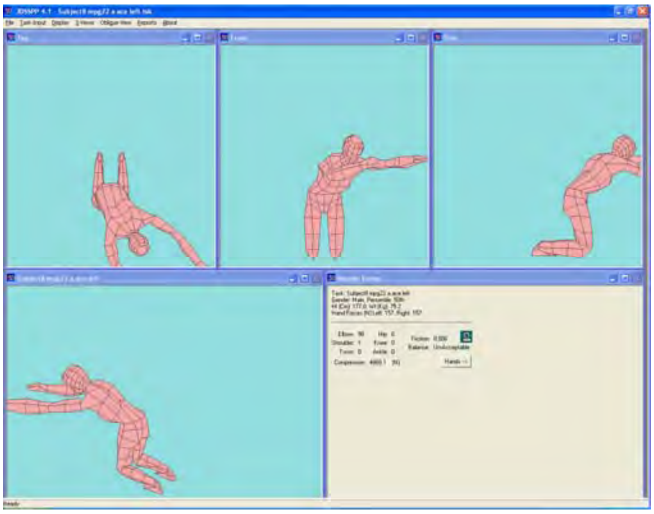


Figure A11.64
Subject 8 - Ace Left

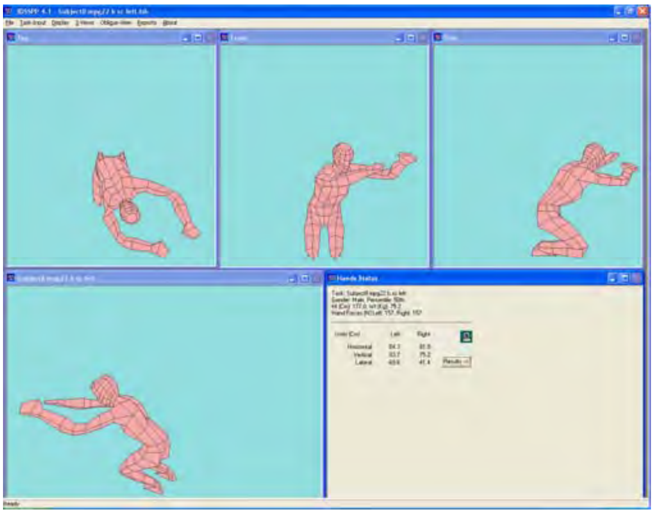


Figure A11.65
Subject 8 – Sliding Carpet Left

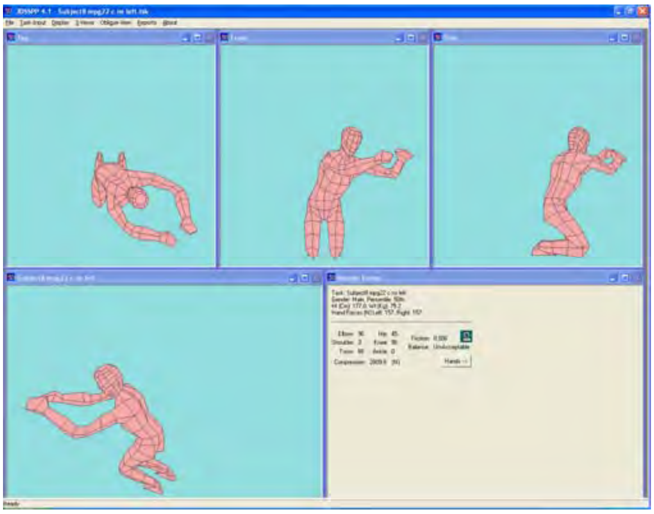


Figure A11.66
Subject 8 – No System Left

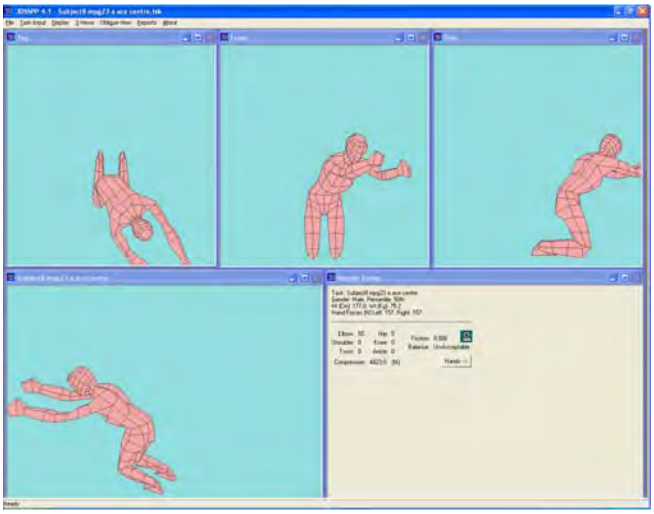


Figure A11.67
Subject 8 Ace Centre–

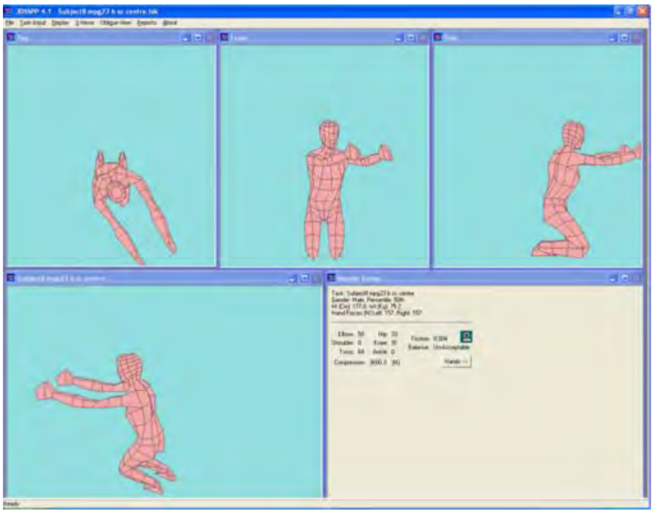


Figure A11.68
Subject 8 Sliding Carpet Centre–

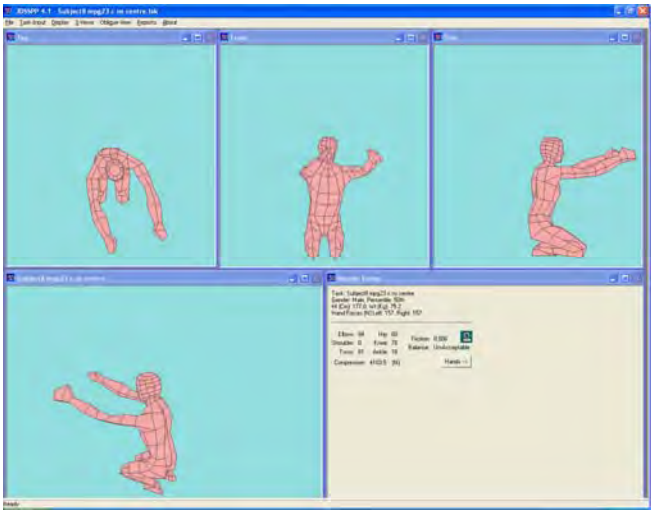


Figure A11.69
Subject 8 No System Centre–

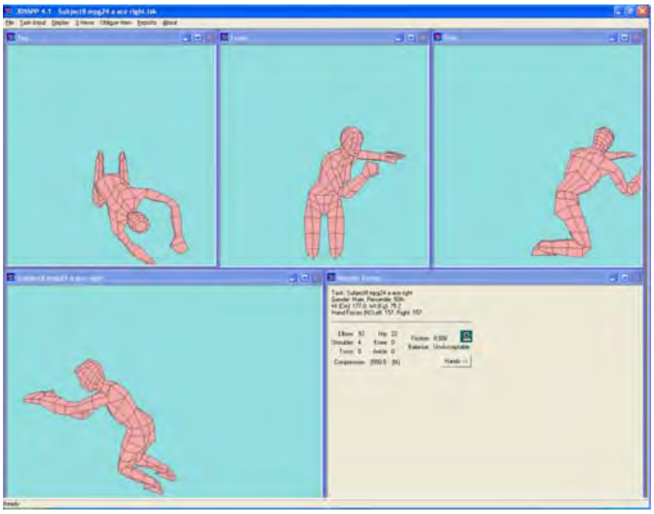


Figure A11.70
Subject 8 Ace Right–

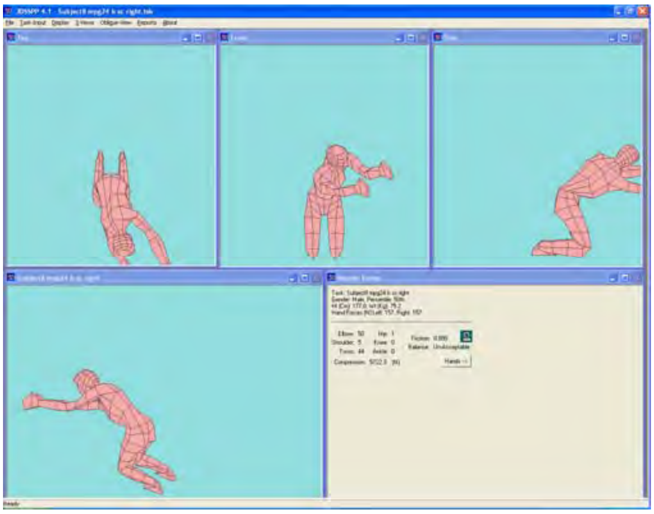


Figure A11.71
Subject 8 Sliding Carpet Right–

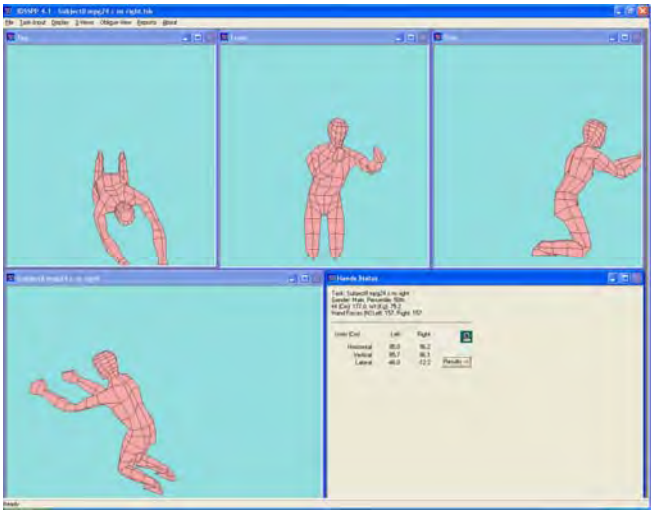


Figure A11.72
Subject 8 No System Right–

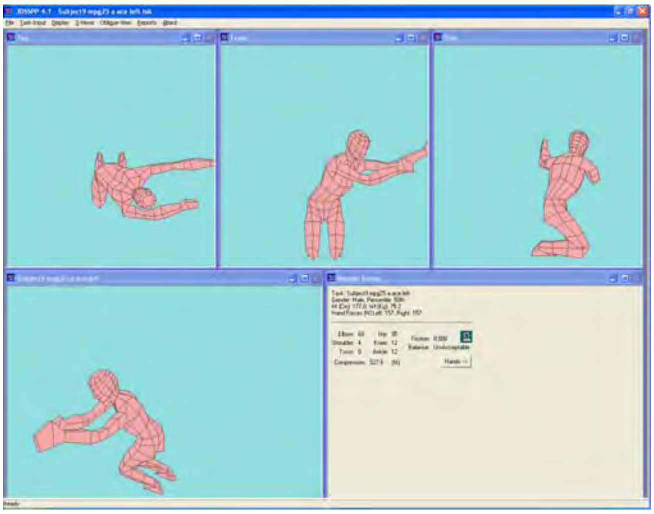


Figure A11.73
Subject 9 - Ace Left

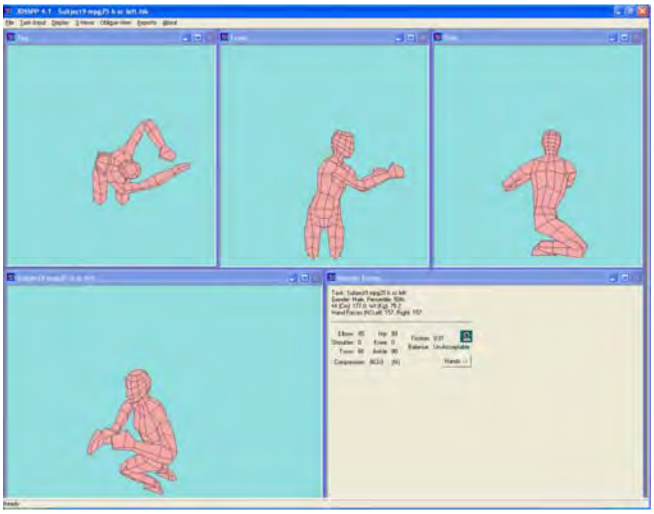


Figure A11.74
Subject 9 – Sliding Carpet Left

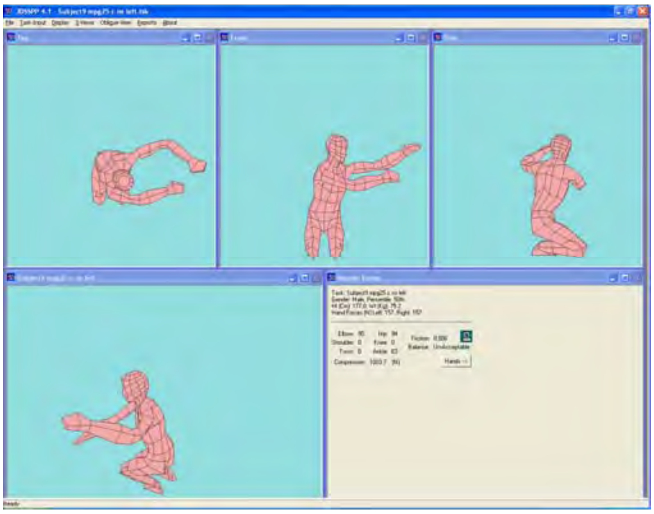


Figure A11.75
Subject 9 – No System Left

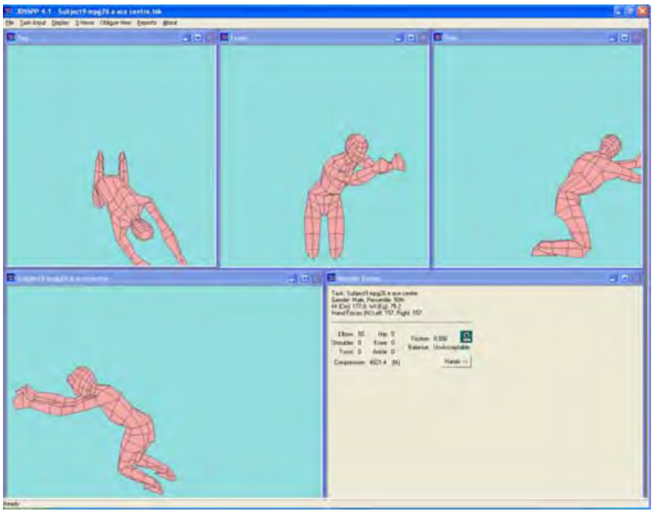


Figure A11.76
Subject 9 Ace Centre–

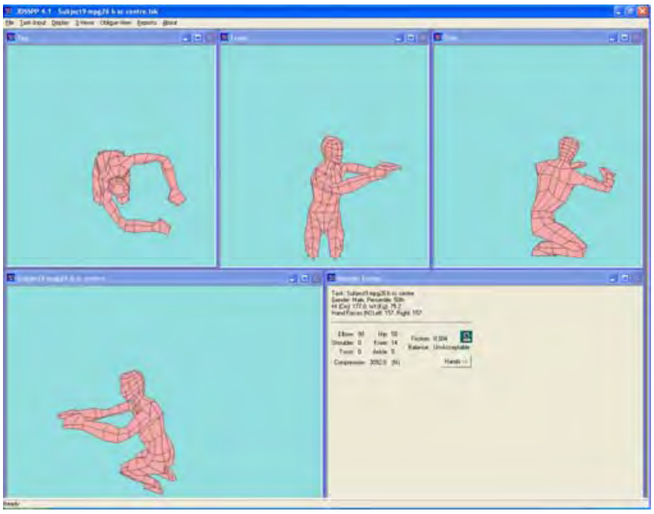


Figure A11.77
Subject 9 Sliding Carpet Centre–

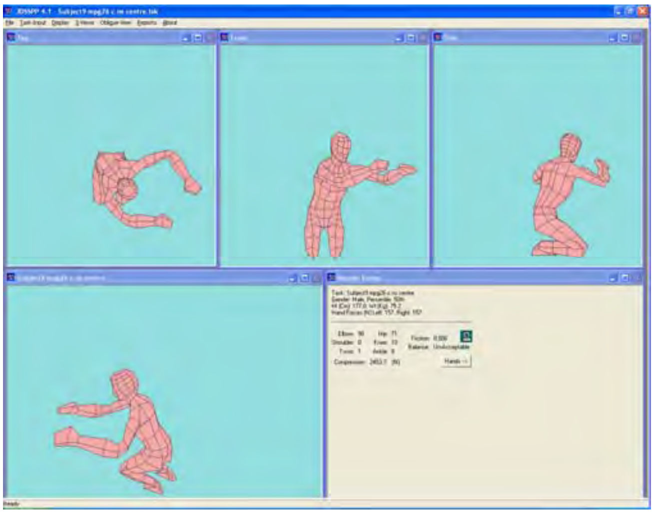


Figure A11.78
Subject 9 No System Centre–

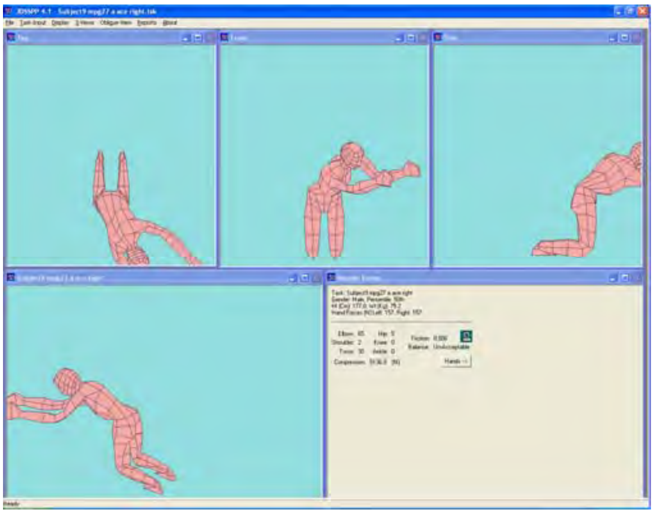


Figure A11.79
Subject 9 Ace Right–

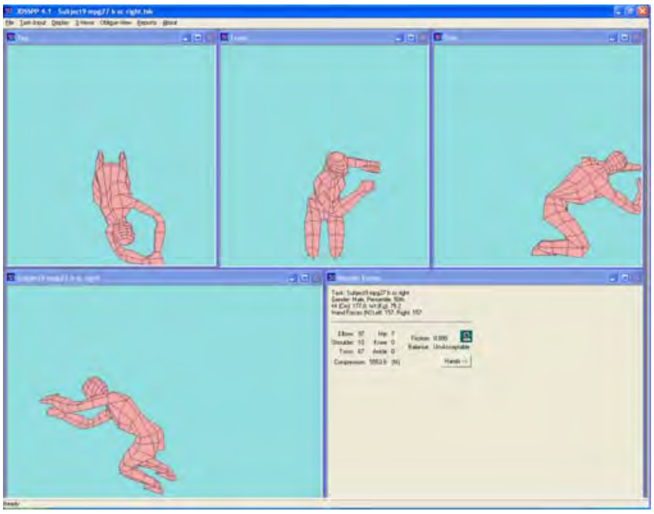


Figure A11.80
Subject 9 Sliding Carpet Right–

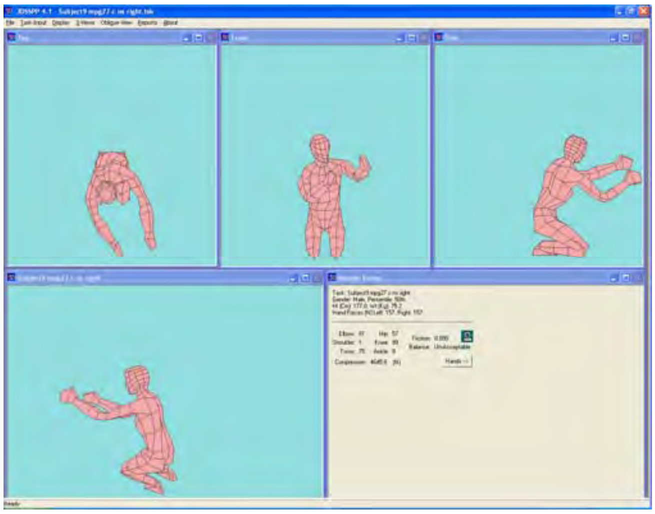


Figure A11.81
Subject 9 No System Right–

APPENDIX NO. 12:

COPY OF LETTER FROM HF&ESA PRESIDENT TO CERTIFIED PRACTICING ERGONOMISTS SEEKING THEIR INPUT TO THE PROJECT

E S A

Human Factors and Ergonomics Society of Australia
CREEDA Business Centre
281 Goyder Street
Narrabundah ACT 2604

Dear Colleague

The Society has been contacted by Mr Geoff Dell, a PhD student from the University of Ballarat whishing to enlist the help of CPEs in his research.

Mr Dell is researching manual handling issues related to airport baggage handlers and in particular he is seeking your opinion on a number of aspects of working posture/s and injury.

If you agree to participate, Mr Dell will forward to you a CD containing mpeg files for you to view, assess and provide feedback to him within a specified timeframe. If you are willing to participate in this valuable research would you please contact Mr Dell on email: gdell@protosafe.com.au

Thank you for your support of this project.

Kind regards

Margaret Head
President

6 December 2004

APPENDIX NO. 13:

COPY OF INTRODUCTORY LETTER TO CERTIFIED PRACTICING ERGONOMISTS

Geoff Dell
PhD Student
University of Ballarat
C/- PO Box 2069
Taylors Lakes Vic 3038
03 9449 1445
0418 367 569
gdell@protosafe.com.au

January 10, 2005

To: All Certified Professional Ergonomists
The Human Factors & Ergonomics Society of Australia Inc
Creeda Business Centre
281 Goyder Street
Narrabundah ACT 2604

Dear ,

RE: PHD RESEARCH - AIRLINE BAGGAGE HANDLER BACK INJURIES: SURVEY OF CPE OPINION

Recently you should have received an email from Margaret Head, President of the Human Factors and Ergonomics Society of Australia, seeking your support and assistance in the conduct of a survey of the HF& ESA's Certified Professional Ergonomist (CPE) group as part of the final phase of my PhD research.

Since the mid-1990s, I have been investigating the causation and prevention of back injuries in the airline baggage handling workforce. The early phases of the project sampled major Australian and overseas airlines, confirmed the high cost, both financial and social, of back injuries to airline baggage handlers, with around one in 12 baggage handlers world-wide suffering a severe back injury each year, costing .

Until the early 1990s, there had been very few attempts in the industry to address the issue. Certainly, the aircraft manufacturers had not addressed the needs of baggage handlers in the design of the aircraft baggage compartments in over 40 years of jet transport aircraft design and operation. However, there were two commercially available retrofit systems which were being advertised as a solution to the baggage handler injury problem, and still are. However, there were no research underpinning the equipment manufacturers' assertions.

My early observations suggested that both systems, one Scandinavian and one American, seemed to eliminate one baggage handling task, but did not seem to appreciably reduce the ergonomic load on the person required to stack passenger bags into the system inside the aircraft. Indeed, it was thought that perhaps one of the systems actually may have increased the risk to the person loading.

Accordingly, it was decided that the final phase of my PhD research would be to attempt to measure any variation in the ergonomic load on baggage handlers using either of the two systems and compare that to loading baggage without either system.

Initially, I videotaped baggage handlers using the systems in normal airline operations. However, it proved very difficult to achieve any fidelity in the data capture since the commercial realities of the airlines' operation tended to interfere and confound the process. Therefore, to provide a controlled environment, we constructed a mock-up of an aircraft baggage compartment in the human movements laboratory at the University of Ballarat. The mockup was designed to simulate a Boeing B737 aircraft baggage compartment with dimensions and adjustable configurations equivalent to both of the two commercially available systems, as well as mimic an aircraft compartment with neither system installed.

In 1999, a series of trials were conducted using baggage handlers provided by Qantas Airways. Qantas provided nine baggage handlers who each loaded bags and suitcases into the mockup three times, once in each simulated aircraft configuration. In each trial run the baggage handler was required to load the baggage in the same way they would normally have loaded the real aircraft. That included grasping the bags and lifting then stacking them into the mockup. Each trial concluded when the baggage handler had filled the space between the mockup floor and ceiling.

Video was captured from three cameras positioned at 90° from one another. One camera was positioned directly above the subject, one behind the subject [as if looking down the centre of the aircraft] and one to the side of the subject, as if looking in through the aircraft doorway or through the fuselage skin.

The video of the trials has been edited into 27 MPEG files. Each MPEG shows three sets of synchronised 3-D views, nine synchronised moving images in all. Each set of three 3-D views are of the same baggage handler loading a bag into the same top row position, each row being a different one of the three aircraft baggage compartment configurations.

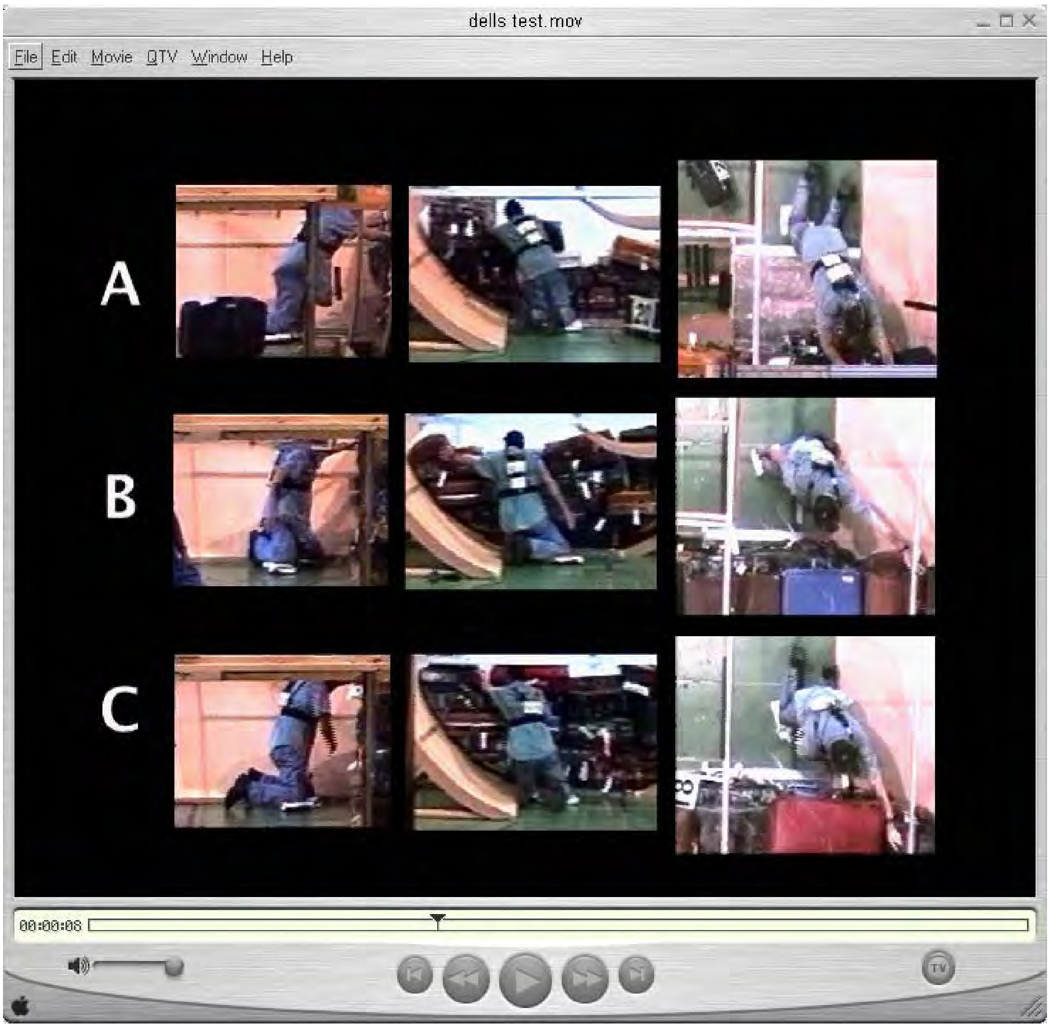


Figure 1

For example, Figure 1 above shows an MPEG still-frame of one subject loading bags into the top left[48] position, in all three aircraft configurations simultaneously. The top row of three images, Row A, are a 3-D view of the baggage handler loading in one aircraft configuration, the middle three 9, Row B, shows him loading in the second configuration and the bottom three, Row C, loading in the third configuration.

The trial was structured to ensure the only variable between each trial run, and therefore between each of the row of 3-D views in the MPEGs, was the changed aircraft baggage compartment configuration..

Using an MPEG player such as Apple QuickTime Player or Windows Media Player, each MPEG allows the observer to watch in real-time the movements and postures of the baggage handler or by using the slider bar on the MPEG player, the observer can slowly step through the loading sequences. The motion in each view has been synchronised using sophisticated video editing technology so that all the bags reach their final position, and the subject has

[48] Top left when viewed from the subject's frame of reference (centre picture in each set of three)

reach their maximum reach extension and trunk rotation simultaneously.

The task I would like all CPEs to carry out, is to view the twenty-seven MPEGS and for each MPEG to compare the three postures adopted by the baggage handler and, based on their professional knowledge and experience, make a judgement on which posture of the three represents the HIGHEST risk of a BACK INJURY and which one represents the LOWEST risk of a BACK INJURY.

I feel certain that all CPEs will consider all of the baggage handling postures depicted as potentially high-risk. The issue I'm trying to ascertain is……Do either of the two commercially available systems make a difference to back injury risk for the people required to load baggage into them, compared to not having either system installed in the aircraft?

This project has the opportunity to make a significant difference to the level of risk experienced by baggage handlers world-wide. The aircraft manufacturers are yet to address the issue in a meaningful way, although we certainly have their attention. Also, some OHS regulators are just now beginning to place pressure on the airlines to find effective controls.

I am sure you would agree its important that the industry finds real and lasting solutions, starting with measuring the effectiveness, or otherwise, of the existing technologies.

There is no doubt that some airlines will purchase the existing systems in the short-term, in an attempt to mitigate the injury risk, especially as the pressure from the regulators' builds. Indeed, quite a few airlines have already purchased systems, at multi-million dollar costs, without really knowing their real OHS benefits.

Accordingly, my project can provide critical guidance to airlines and ensure the most effective solutions are adopted in the short-term, and possibly provide a focus on the need for long-term automation solutions. In this regard, the CPE's can make a valuable contribution by participating in the project.

The Project is covered by University of Ballarat Ethics Human Research Committee approval. The identity of individual CPEs will not be revealed. The responses will be aggregated to provide an indication of the collective judgement of the CPE group.

Your support and that of the Human Factors and Ergonomics Society of Australia, is very much appreciated and will be formally acknowledged in my Thesis.

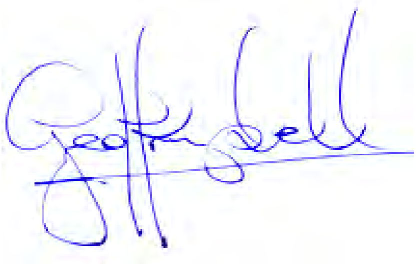
Enclosed with this letter you will find a CD containing:

1. The 27 MPEG files
2. The Plain Language Statement describing the survey task and contacts for the University of Ballarat, Human Research Ethics Committee, should you have the need to do so.

3. An Agreement to Participate Form
4. A Survey Response Form
5. A "read me" file of instructions.

I look forward to receiving your response to the survey. Should you have any questions or concerns, please do not hesitate to contact me on 03 9449 1445, 0418 367 569 or gdell@protosafe.com.au.

Yours sincerely



Geoff Dell

cc Professor Dennis Else, University of Ballarat

APPENDIX NO. 14:

THE PLAIN LANGUAGE STATEMENT FROM THE UNIVERSITY OF BALLARAT ETHICS COMMITTEE APPROVAL

Comparison of three common B737 aircraft baggage compartment configurations and resultant baggage handler techniques: Perceptions of the difference in injury risk to baggage handlers using the three configurations

Principal Investigator: Professor Dennis Else

Associate Investigator: Mr Geoff Dell

Dear Participant,

We wish to invite you to participate in this study comparing three common baggage-handling configurations and resultant baggage handler techniques. If you choose to participate in this research you will be asked to to examine twenty seven sets of three photographs of baggage-handlers stacking baggage. Each set being the same baggage handler stacking baggage into the same location using each of the three aircraft configurations. You will be asked to compare the three sets and give your opinion on which set the posture adopted by the baggage handler would have the highest risk of a back injury and in which set the posture adopted by the baggage handler would have the least risk of a back injury. You will be required to answer every question for your responses to be included in the final data set. This research is confidential and anonymous. You can not be identified from the data provided. All information will only be used for this research. All data will be kept securely by the researchers. Completion of the questionnaire will take approximately 30 minutes of your time.

Boeing B737 aircraft baggage compartments typically are configured by airlines in one of three ways. They are fitted with either of two commercially available baggage systems or are operated with no baggage system at all. The two narrow body stacking systems are commonly theorized to reduce the risk of back injury to baggage-handlers. Although many people in the aviation industry suggest these systems are the solution, there is very little data available to validate that contention.

Accordingly, this research will add valuable data, from ergonomic specialists, which could be pivotal in terms of future worldwide baggage handler injury prevention effort.

If you would like to participate in this research please, enter your name below, print and sign the form, and fax to 03 9449 1445 or email gdell@protosafe.com.au with *Back Injury Survey - I Agree* in the subject line of the email. You are free to withdraw from the study at anytime, prior to submitting your survey responses. Due to the anonymous nature of this research, after you have submitted your responses, we cannot withdraw you from the study.

If you do not wish to participate, thank you for taking the time to read the documentation.
If you have any questions regarding this research please contact the Principal Investigator Professor Dennis Else at VIOSH Australia, School of Science and Engineering, University of Ballarat, on **+61 3 53279150.**

Thank you for your time.

NAME………………………………..SIGNATURE…………………..…………………I AGREE

Should you (i.e. the participant) have any concerns about the conduct of this research project, please contact the Executive Officer, Human Research Ethics Committee, Office of Research, University of Ballarat, PO Box 663, Mt Helen VIC 3353. Telephone: (03) 5327 9765.

APPENDIX NO. 15:

CPE SURVEY RESPONSE FORM

**AIRLINE BAGGAGE HANDLER BACK INJURIES:
SURVEY OF CPE OPINION**

PLEASE COMPLETE THE FOLLOWING TABLE:
BY WRITING/TYPING THE LETTER OF THE ROW YOU CHOOSE FOR MOST LIKELY

EXAMPLE

MPEG FILE NO.	HIGHEST RISK of a Back Injury	LOWEST RISK of a Back Injury
23	C	A

Enter the letter designating the ***ROW*** in the MPEG you consider depicts the postures with the ***HIGHEST*** risk of **back** injury

Enter the letter designating the ***ROW*** in the MPEG you consider depicts the postures with the ***LOWEST*** risk of **back** injury

SURVEY RESPONSES

MPEG FILE NO.	HIGHEST RISK of a **Back** Injury	LOWEST RISK of a **Back** Injury
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		
25		
26		
27		

THANK-YOU FOR YOUR TIME AND EFFORT TAKEN TO RESPOND TO THIS OPINION SURVEY

Please email completed survey to gdell@protosafe.com.au or fax 03 9449 7118.

APPENDIX NO. 16:
CPE SURVEY README FILE: RUNNING THE MPEG FILES

AIRLINE BAGGAGE HANDLER BACK INJURIES:
SURVEY OF CPE OPINION

RUNNING THE MPEG FILES

1. The mpegs are formatted to run using most of the movie players presently available, such as ***APPLE QUICKTIME*** PLAYER, ***WINDOWS MEDIA PLAYER*** and ***REALONE PLAYER***.

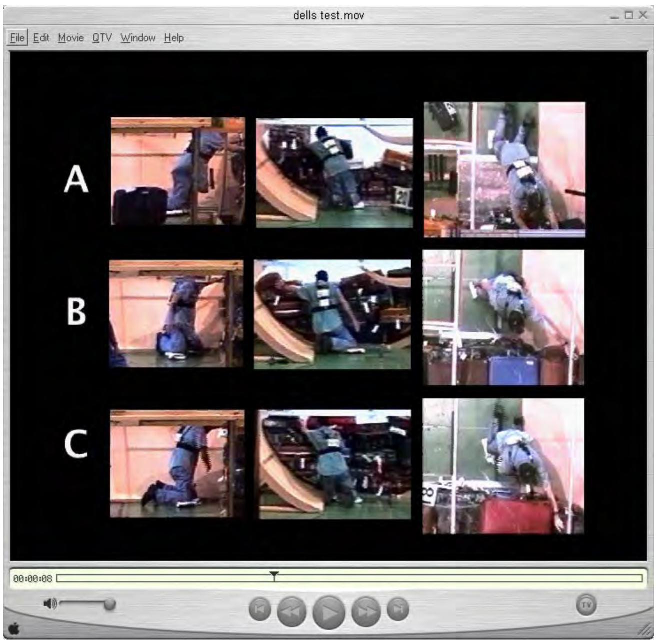
2. In some viewers, like ***APPLE QUICKTIME*** PLAYER, it will be necessary to select MPEG in the "file type" drop down window to see the MPEG files in the "File-Open" window.

3. Once a file is opened, in some players you will need to push the start button to begin the motion.

4. After the motion has run for the first time, pulling the scroll bar at the bottom allows you to step through the loading sequence to observe the postures more closely.

Note: we have found ***APPLE QUICKTIME*** PLAYER to be the most effective as it allows for larger screen sizes to aid viewing while using the scroll bar to step through the sequences. Some other viewers disable the scroll bar when the screen is enlarged to full screen.

Should you wish to do so, ***APPLE QUICKTIME*** PLAYER is available free by download from www.apple.com , although download time is around **one hour** with a normal dial-up connection.



APPENDIX NO. 17:
STATISTICAL VALIDATION TESTS

Normality Tests Used:

Shapiro-Wilk Test: According to, the Shapiro-Wilk Test is the preferred test of normality “*because of its good power properties as compared to a wide range of alternative tests used in testing for normality*”. When the Shapiro-Wilk Test statistic “W” is significant, then the hypothesis that the distribution is normal should be rejected *Statsoft (2004)*.

Jarque-Bera Test: The Jarque-Bera Test evaluated the hypothesis that the data set had a normal distribution with unspecified mean and variance, against the alternative that it did not have a normal distribution. The test is based on the sample and kurtosis, a measure of peakedness of the distribution and its skewness. A normal distribution would feature skewness approaching The Jarque-Bera test ascertains whether the skewness and kurtosis are extraordinarily different than the expected values measured by the chi-square statistic. (*StatSoft (2004)* and *MathWorks (2005*))

Anderson-Darling Test: The *Anderson-Darling* test compared the fit of any cumulative distribution of the data sets to an expected cumulative distribution. This test was applicable to complete data sets as was the case in these data analyses. The Anderson-Darling test was designed for sample sizes between 10 and 40 (*StatSoft (2004)*.

Lilliefors Test: The Lilliefors test should be used when the mean and standard deviation of a normally distributed population is not previously known but calculated from the sample data. The test estimates the probability that the Kolmogorov-Smirnov “D” statistic was significant based on the mean and standard deviation computed from the data.

Validation Tests of Variance and Tests of Difference used in this Study

Parametric Tests

The parametric tests utilised for the validation tests in this study were (see *StatSoft (2004), NIST (2005)* and *MathWorks (2005*):

Students t-test: Student t-tests, a commonly used method to evaluate the differences in means between two data sets, can be used for small sample sizes as long as the distribution of the two samples was normal and the variation of scores within each set was not very different. The resultant measure was a probability of error that rejecting the hypothesis that there was no difference between the two data sets.

Z test: The Z-tests are used to find significant differences between the mean of a population and a sample from the same population. However, the statistics literature indicates that when a z test is used to compare the means of two separate populations, it returns the same result as a t-test, although with different assumptions and methods intrinsic to its methodology. Because of these differences, the Z test was used in this study where indicated to provided a measure of the differences between the means of the data groups. The test returns the probability that differences are due to chance and the null hypothesis that the sample and population means are not different can be rejected.

Bartletts Test: Bartlett's test was used to test if the scores in the data sets had equal variances. The test is sensitive to departures from normality and returns the upper limit of a Chi square distribution corresponding to the 0.05 level of significance (95% confidence) and the null hypothesis, that there was no difference in the variances, was rejected if the Bartlett test statistic result was greater than the critical value.

Levene's Test: Reported to be an alternative to the Bartlett Test, Levene's test also tested if the scores in the data sets had equal variances. The test is said to be less sensitive to departures from normality Like Bartlett's, Leven's test tests the hypothesis that the variances are equal. It returns the upper limit of an F- distribution corresponding to the 0.05 level of significance (95% confidence) and the null hypothesis, that there was no difference in the variances, was rejected if the resultant Levene's test statistic was greater than the critical value.

Non-parametric Tests

The non-parametric tests utilised in the statistical analysis in this study were (see StatSoft (2004), NIST (2005) and MathWorks (2005):

Mann-Whitney Test: The Wilcoxon Mann-Whitney Test is reported to be one of the most powerful of the non-parametric tests for comparing two populations. It is used to test the null hypothesis that two populations have the same medians. The test allows selection of one tailed analysis or two tailed analysis and returns critical value/s and the null hypothesis was rejected if the calculated Z-test statistic was outside the critical values range for a two tailed test or above or below, dependent on direction the critical value for a one tailed.

Kolmogorov-Smirnov two sample test: The Kolmogorov-Smirnov test was used to determine if two data sets come from a population with a specific distribution. The Kolmogorov-Smirnov test statistic does not depend on the underlying cumulative distribution of the data being tested and is an exact test in that the underpinning chi-square goodness-of-fit test depends on an adequate sample size for the results to be compelling *NIST (2005)*. The null hypothesis that the samples were no different was rejected when the test statistic "D" was greater than the critical value "p".

Kruskal Wallis Test: The Kruskal Wallis Test compared two or more independent samples. The test compared the medians of the samples and returned the critical value "H" and the observed value "H" and a probability "p". The null hypothesis of the absence of difference between the data sets was rejected probability values was lower than the 0.05 significance level.

Wilcoxon Signed Rank Test: The Wilcoxon Singed Rank Test for two paired samples the magnitude of the differences in the paired observations and ranks them bu absolute value. The literature indicates that for small numbers ($n<50$) with unknown distributions, the test was more sensitive than the Student t-test. It returns an expected value of its “T” statistic and the actual value based on the sample pairs and a probability “p” value. The null hypothesis that the samples are not different is rejected when the p-value is less than the 0.05 significance level.

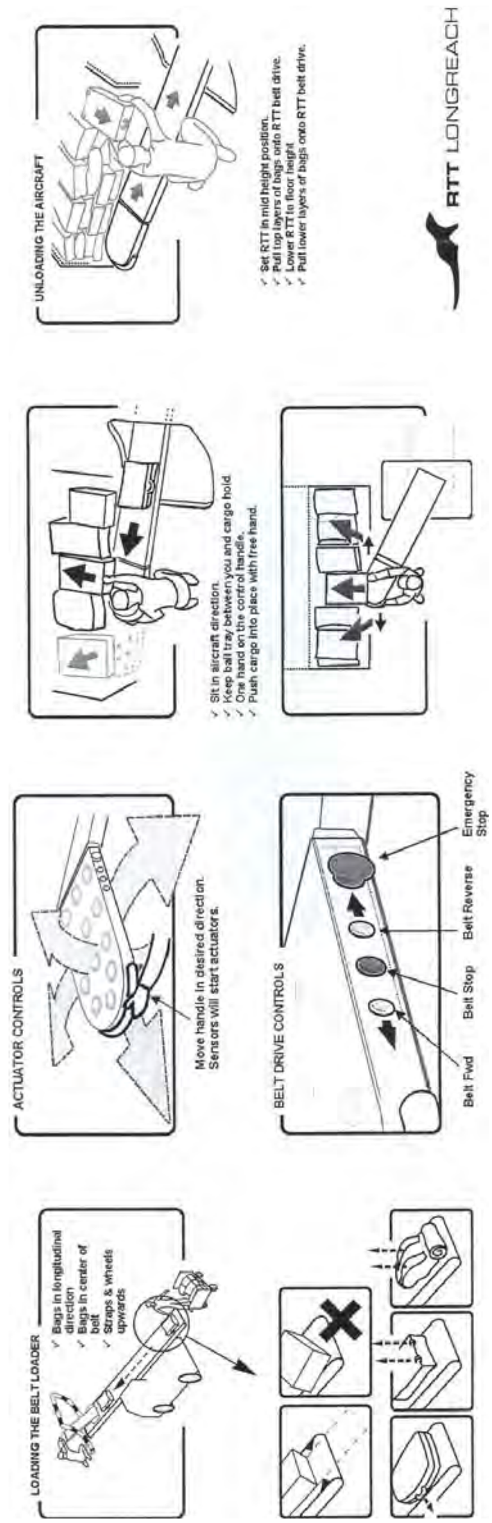
Sign Test: The Sign test for paired data is reported to be the crudest and most insensitive test but the most convincing test while simple and easy to apply. The literature suggests if the sign test indicates significant difference and another does not, then there was probably grounds to suggest the other test was not valid. The test returned the number of differences identified and a probability “p” value which if below the 0.05 significance level, the null hypothesis that the samples were not different was rejected.

Freidman’s Test: Friedman’s test was for data having a two-way relationship. It did not treat the two factors symmetrically and it did not test for an interaction between them. It tested if the data columns were different after adjusting for possible row differences. The test returns the observed value of its statistic “Q” and the critical value of “Q”. The null hypothesis of the absence of difference between the data sets was rejected when the probability “p” was below the significance level 0.05.

Multiple Comparisons Test: The Multiple Comparisons Test for two or more samples compares the data in the multiple data sets and returns a matrix of pairwise comparisons or groups calculated at the 0.05 significance level. The null hypothesis of no differences was rejected if the pairwise comparisons resulted in data sets being assigned to different groups by the test.

Where any of the tests in this study required manual input of “one” or “two” tailed tests, two tailed tests were selected since the direction of any difference between data sets was not assumed in advance of the tests. However, some tests automatically made assumptions based on the nature of the data sets, for example the Kruskal-Wallis test, and delivered one-tailed significance test results.

APPENDIX NO. 18:
TELAIR INTERNATIONAL RTT LONGREACH LOADER DRAFT OPERATING PROCEDURES



APPENDIX NO. 19:
RISK ASSESSMENT PRO-FORMA USED RTT LONGREACH LOADER MANUAL HANDLING ASSESSMENT

PROTOTYPE TELAIR LONGREACH LOADER MANUAL HANDLING RISK ASSESSMENT

DATE:	FACILITATOR:	Page 1 of x
AREA/LOCATION:	**EQUIPMENT TYPE: LONGREACH LOADER**	
RISK ASSESSMENT TEAM		

HAZ NO.	CATEGORY	HAZARD	CURRENT CONTROLS	STRENGTHS & WEAKNESSES	RISK SCORE
ASSESSMENT OF AIRCRAFT LOADING RISK WITHOUT LONGREACH LOADER					
1	ERGONOMICS				
ASSESSMENT OF ERGONOMICS ISSUES WITH USE OF LONGREACH LOADER					
2	ERGONOMICS				
3	ERGONOMICS				
4	ERGONOMICS				
5	ERGONOMICS				
6	ERGONOMICS				
7	ERGONOMICS				
8	ERGONOMICS				
9	ERGONOMICS				
10	ERGONOMICS				

COMMENTS:

CATEGORIES:	**Biological** ie Hep A, HIV	**Ergonomic** ie Manual handling, OOS
Physical ie Noise, temp, light, radiation, etc	**Psychological** ie Stress, violence	**Slips/trips/falls** ie Falls from height / same level
Chemical ie Hazard /dangerous goods, spills	**Fire / Explosion** ie Gas, petrol, combustible	**Confined space** ie Vessels, pits, tanks
Mechanical ie Plant (crush, entanglement, hit, cut)	**Electrical** ie Power point, cables	Some categories may require detailed assessments

PROTOTYPE TELAIR LONGREACH LOADER MANUAL HANDLING RISK ASSESSMENT

DATE:	FACILITATOR:	Page 2 of x
AREA/LOCATION:	**EQUIPMENT TYPE: LONGREACH LOADER**	
RISK ASSESSMENT TEAM		

CONTROL ACTION PLAN

Haz No.	INTERVENTION STRATEGIES	STRENGTHS & WEAKNESSES	RISK SCORE
ASSESSMENT OF AIRCRAFT LOADING RISK WITH LONGREACH LOADER			
1			
ASSESSMENT OF ERGONOMICS ISSUES WITH USE OF LONGREACH LOADER			
2			
3			
4			
5			
6			
7			
8			
9			
10			

CATEGORIES:
Physical ie Noise, temp, light, radiation, etc
Chemical ie Hazard /dangerous goods, spills
Mechanical ie Plant (crush, entanglement, hit, cut)
Biological ie Hep A, HIV
Psychological ie Stress, violence
Fire / Explosion ie Gas, petrol, combustible
Electrical ie Power point, cables
Ergonomic ie Manual handling, OOS
Slips/trips/falls ie Falls from height / same level
Confined space ie Vessels, pits, tanks
Some categories may require detailed assessments

APPENDIX NO. 20:
PEER REVIEWED PAPER: SAFETY SCIENCE MONITOR – *"THE CAUSES AND PREVENTION OF BAGGAGE HANDLER BACK INJURIES: A SURVEY OF AIRLINE SAFETY PROFESSIONALS"*

THE CAUSES AND PREVENTION OF BAGGAGE HANDLER BACK INJURIES:

A SURVEY OF AIRLINE SAFETY PROFESSIONALS

by

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ABSTRACT

Back injuries to baggage handlers collectively cost 15 airlines and a ground handling company an average of $US21 million per annum over the period 1992-1994. The annual Lost Time Injury Frequency Rates (per million hours worked) for the period exceeded 41.5 and 8.5 % of the baggage handler workforce suffered back injuries each year. This paper surveyed the Safety Professionals of 15 major airlines and a ground handling company, to identify the cost of baggage handler back injuries and the rates of occurrence of those injuries. The opinion of the Safety Professionals regarding back injury causation and prevention was also sought. The need for re-design of some aircraft baggage compartments, baggage handling systems, equipment and airport terminal facilities was identified.

THE BACK INJURY PROBLEM

Of all types of occupational trauma, back injuries represent one of the largest groups. *Saraste (1993)*, in a study of Swedish male workers with back ailments, and *Stubbs (1986)* in a report of a study of the nursing profession in England, both suggested that 80% of workers experienced lower back ailments during their working life. In 1987 back injuries accounted for 27% of all lost time compensation claims in Ontario Canada (*WCB (1988)*), and a similar proportion of back injuries was reported more recently by *Workcover New South Wales (1996)*, who reported back injuries to be 30% of all New South Wales workplace injuries in the period 1993 to1995 inclusive. Statistics published by the Victorian Health and Safety Organisation showed that 25.0% of all workers compensation claims lodged for the period July 1992 to June 1994, across all industries in Victoria, recorded back injuries as the most serious suffered by the claimants (*Health and Safety Organisation (1995)*). Furthermore, *NIOSH (1994[1])* reported that back injuries accounted for 20% of all injuries and illnesses in USA workplaces, costing in excess of 20 billion dollars per year.

Anecdotal evidence available in 1994 *(Dell 1994)*, indicated that back injuries to airline baggage handlers[1] also cost the aviation industry millions of dollars per annum and some airlines had over 20% of their baggage handler work force absent due to back injuries at any one time. Subsequently, in 1995 discussions were held by the writer with key engineering and safety staff of aircraft manufacturers Boeing, McDonnell Douglas, Avro, Airbus Industrie and Fokker. While all showed an interest in the back injury subject, the issue had not been raised with them before. All highlighted the need for accurate quantitative data on the cost of these injuries and the magnitude of the problem, if the issue was to be factored into manufacturers' aircraft design criteria in the future. At the time, the quantitative data was not readily available.

This paper quantifies the magnitude of the back injury problem amongst airline industry baggage and cargo handlers. By canvassing safety professionals working in the industry, it also identifies the high risk baggage handling tasks and investigates some likely solutions. The paper is one in a series by the writer looking into various aspects of the baggage handler injury problem.

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[1] For the purpose of this study, a baggage handler is defined as a person who loads or unloads baggage and or cargo from commercial transport aircraft. It includes those persons who work within the airport terminal who handle baggage and those who consolidate baggage and cargo for particular flights.

METHODOLOGY

A questionnaire was developed and circulated to the occupational health and safety professionals of 32 major companies worldwide who employ baggage or cargo loading staff. Seventeen responded, however, one provided insufficient information to be included in the data set. The sixteen companies who provided useable data were: Sabena Belgian Airlines, Thai Airways International, Swissair, Qantas Airways, Air New Zealand, Canadian Regional Airlines, DHL Aviation, Canadian Airlines International, Hong Kong Air Terminal Services, Delta Airlines (Germany) , Ansett Australia, KLM, Ansett New Zealand, Eagle Airways, Delta Airlines (USA) and American Airlines.

The questionnaire was in two parts, those questions intended to quantify the costs and magnitude of the back injury problem (Part A) and those intended to investigate the causes and any preventive measures their organisations had attempted (Part B), as follows:

PART A

In order to validate the anecdotal information on the magnitude of the baggage handler back injury problem, the industry safety professionals were asked, for the years 1992, 1993 and 1994, to provide the following information related to their operation:

- The number of baggage handlers employed per annum.
- The average number of hours worked per week per baggage handler
- The number of lost time back injuries[2] per annum
- The annual cost of those injuries.[3]

Response data obtained was used to calculate annual lost time injury frequency rates per million hours worked (LTFRs) for the total baggage handler population and the average cost per injury per annum.

PART B

The questionnaire also canvassed the following information from the safety professionals:

- Whether baggage handlers in their organisation were required to lift baggage and cargo exceeding 32Kg (70lb) weight? 32Kg is a pre-existing notional industry limit on passenger baggage weight.
- From a list of twelve manual handling tasks routinely carried out by baggage handlers, which did they consider to be the five (5) most likely to cause baggage handler back injuries?
- What back injury control measures had been applied in their companies? In particular, information was sought on use of back support belts, back care training, use of ground equipment, use of narrow body aircraft in-plane baggage stacking systems and details of any attempts at building re-design to reduce the instance of baggage handler manual handling injuries.
- What measures did they believe would be necessary in future to reduce the instance of back injuries to baggage handlers?

[2] Lost Time Back Injury was defined as the failure, following the injury, to report for duty at commencement of the next work shift.
[3] Cost was defined as including workers compensation, medical and rehabilitation expenses.

RESULTS

The reported cost of back injuries in the baggage handler work force of the respondent organisations collectively rose from $US 17,639,857 in 1992 to $US 23,697,170 in 1993 and dropped slightly to $US 21,710,953 in 1994. The total number of lost time back injuries rose from 1570 in 1992 to 2408 in 1993 and then remain almost unchanged at 2405 in 1994. Figure 1 summarises the responses to the questions in Part A, as well as the LTFRs and average back injury costs calculated from those responses. LTFRs calculated from the respondent data were 42.5 for 1992, 41.5 for 1993 and 43.5 for 1994. Average cost per back injury reduced over the period from $US 11,236 in 1992 to $US 9,841 in 1993 and $US 9027 in 1994.

Figure 1
The Back Injury Problem Quantified

	1992	1993	1994
No of Baggage Handlers	19430	30257	29099
Av. Hours Worked/ Person/Week	38.0	38.4	38.4
No of Lost Time Back Injuries	1570	2408	2405
Annual Cost ($US)	$17,639,857	$23,697,170	$21,710,953
Lost Time Injury Frequency (per 10^6 hours worked)	42.5	41.5	43.5
Average Cost Per Back Injury ($US)	$11,236	$9841	$9027

In addition to the questions concerning costs and injury frequency, the Safety Professionals were asked to rank the following workplaces in order from that which they considered were most likely to be the site of a back injury, to those which were least likely. The work places were: Baggage check-in; Baggage make-up room; Inside narrow body aircraft; Inside wide body aircraft bulk hold, and; Outside aircraft on the ramp. Figure 2 shows that 10 of the 16 respondents felt that the highest injury risk location to be "Inside Narrow Body Aircraft

Figure 2 **Manual Handling Locations Ranked *MOST* Likely to Cause Injury**	f (n=16)
Baggage Check-in	1
Baggage Make-up Room	2
Inside Narrow Body Aircraft Baggage Compartments	10
Inside Wide Body Aircraft Bulk Hold	0
Outside Aircraft On the Tarmac	3

With regard to which baggage handling tasks were considered most likely to cause back injury, 14 of the 16 respondents selected "Stacking Baggage inside the Baggage Compartment of Narrow Body Aircraft" as one of their top 5 high risk tasks (see Figure 3). This was closely followed by "Pushing Baggage from the Doorway into the Baggage Compartment of Narrow Body Aircraft" and "Transferring Baggage from a Trailer directly into a Narrow Body Aircraft" (11 responses each) and "Pushing and Pulling Containers and Pallets inside Wide Body Aircraft", which only occurs when the aircraft's built in equipment is broken, was ranked as the fourth most likely injury causation task (9 responses).

Fifteen of the Safety Professionals surveyed in this study indicated that baggage handlers in their organisations were required to lift baggage weighing in excess of 32kgs(70lbs). Ten of the Respondents in this survey also felt enforced limitations were necessary.

Since a number of airline baggage handlers around the world were reported to be using various types of back support belts, the Safety Professionals were asked to indicate whether their organisations had used such belts as a measure to control back injuries in baggage handlers. However, there was no conclusive outcome. Only 2 respondents reported that a back support belts were used in their airlines. One of these indicated that introduction of the belts had made no difference to the instance of baggage handler back injuries, while the other claimed a 60% improvement in injury occurrence.

Figure 3 **Manual Handling Tasks Ranked *MOST* Likely to Cause Injury**	f (n=80)
Lifting Baggage on or off Scales at Check-in	2
Loading Baggage onto Trailers in the Baggage Make-up Room	8
Loading Containers in the Baggage Room	6
Unloading Baggage Trailers in the Baggage Room	3
Unloading Containers in the Baggage Room	1
Pushing and Pulling Loaded Baggage Trailers, Containers and Pallet Dollies	7
Transferring Baggage from a Trailer to Mobile Belt Positioned at the Aircraft	2
Transferring Baggage from a Trailer Directly Into an Aircraft through the Cargo Door	11
Pushing Baggage from the Doorway into the Baggage Compartment of Narrow Body Aircraft	11
Stacking Baggage Inside the Baggage Compartment of Narrow Body Aircraft	14
Pushing and Pulling Containers and pallets Inside Wide Body Aircraft	9
Stacking Baggage in the Bulk Hold of Wide Body Aircraft	6

The industry Safety Professionals were also asked whether Back Care Training was used as an injury control measure in their airlines, and if so, what impact had the training had on the instance or severity of back injuries. It is significant that while 12 of the 16 respondents reported that Back Care Training was provided to staff, only 2 reported that the training had any effect on their back injury rates. 10 of the Respondents in this study felt better training was a viable option.

Eleven respondents reported that their airlines used ground equipment to reduce the manual handling risk to baggage handlers. However, only 1 reported that use of ground equipment had resulted in an improvement in injury occurrence (10%).

Nine of the 16 Safety Professionals indicated that manual handling tasks associated with pushing and pulling baggage containers and pallets were a significant injury risk when equipment was broken or otherwise unserviceable.

Only 6 respondents reported their organisations' having reviewed the design of buildings, and just one was able to suggest that an injury rate reduction occurred. None had provided mechanical lifting aids to assist with baggage handling tasks.

DISCUSSION

The Figure 1 data removes any doubt about the industry's need to take positive back injury prevention steps. These LTFRs for baggage handler back injuries can only be described as abysmal. Worlds best practice organisations, for example Du Pont *(Brock 1996)* and ICI Australia *(ICI Australia 1996)* consistently experience LTFRs below 1.0.

While the average cost per injury reduced over the 3 year period by 19.6%, the LTFR fluctuated above 41.5 indicating that over 8% of the baggage handler work force experienced lost time back injuries each year.[4]

[4] LTFR of 41.5 equates to 8.3%. For every 500 baggage handlers employed in the study group organisations in 1993, 41.5 (8.3%) experienced lost time back injuries (assumes a 40 hour working week and a 50 week working year [ie 10^6 hours worked = 500 people x 40 hours x 50 weeks]).

The consistent poor performance over the three year period would also suggest any pre-existing injury prevention programs had been ineffective at reducing the instance of lost time baggage handler back injuries to an acceptable standard.

There is no doubt that the back injury problem is exacerbated by the poor lifting postures which baggage handlers must adopt in some cases, particularly those inside aircraft baggage compartments (see Figure 4).

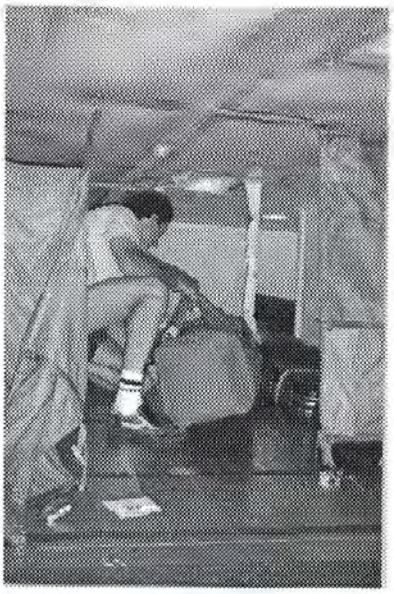

Figure 4
Loading Inside Aircraft Baggage Compartments

Hogwood (1996) suggested that aircraft cargo compartments are ergonomic disaster areas. Of this there is little doubt. While most, if not all, modern passenger aircraft have the latest technology systems installed in the cockpit and passenger cabins, there is no similar situation below the cabin floor. The baggage compartment, particularly in narrow body aircraft such as the Boeing B737, McDonnell Douglas DC9, British Aerospace BAe146 and Fokker F100, is little more than a space left for the purpose of stacking baggage and cargo. Manual handling is usually the only option available to load and unload the aircraft.

Consistent with earlier studies of this matter (*ARTEX (1980) , Dell (1994) & Hogwood (1996)*), the majority of respondents in this study felt the narrow body aircraft baggage compartment represented a high injury risk. However, it is of interest to note that none of the respondents felt that working inside the bulk hold of wide-bodied aircraft presented a greater risk of injury than working in the baggage make-up room, outside the aircraft on the ramp, or in the baggage check-in area. Yet the dimensions of the bulk hold of wide body aircraft are smaller in many cases, than those of narrow body aircraft cargo compartments and as such, are more restrictive on baggage handler working posture.

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There is clearly a need to address these aircraft design shortcomings. However, as *Briggs (1997)* stressed, *"there will have to be airline industry consensus before the aircraft manufacturers will carry out design changes to their aircraft"*. This suggests the manufacturers will only react to market demand. So why have the airlines not demanded such changes long before now? The answer is simple. In the past, aircraft were designed to satisfy three criteria required by the airlines: range, payload and low operating cost, especially low fuel burn. Accordingly, only those systems essential for the airliner's operation were considered in the design. Thus, keeping the weight of the aircraft as low as possible, directly reduced the resultant fuel burn and maximised the potential payload capabilities of the design. The cost of injuries to baggage handlers was never factored into the equation.

In the manufacturers' defence, the actual costs of those injuries were not well known, until now. Consolidated for the first time in this study, baggage handler injury costs should be factored into all future aircraft design specifications. If the manufacturers will not react without the airlines' consensus, then it becomes the role of the airlines' safety professionals to ensure their airlines firstly address the issue internally, then begin to put pressure on the manufacturers for design solutions to the back injury problem.

Some airlines have retro-fitted semi automated systems in baggage compartments in narrow body aircraft. These systems provide a moveable wall which can be positioned near the cargo compartment door and eliminate the need for baggage to be shifted manually down the length of the cargo compartment. However, these systems still require the baggage handler to stack the baggage in the baggage compartment. Figure 5 depicts the Scandinavian Belly Loading Company "Sliding Carpet" system

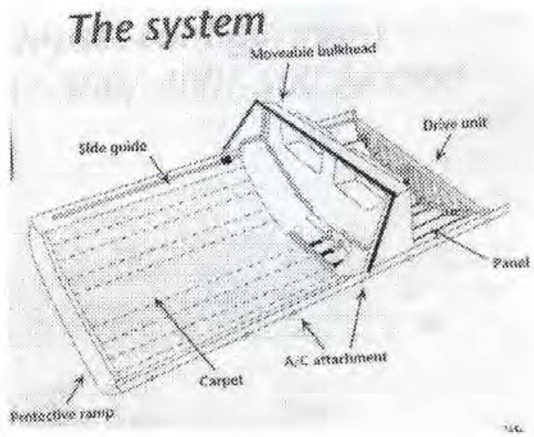

Figure 5
Scandinavian Belly Loading Company Sliding Carpet Loading System

Although not yet in wide spread use, systems such as *Sliding Carpet* have been installed by some airlines and information available to date is encouraging. For example, *Johansen (1995)* reported a 25% reduction in baggage handler sick leave rates, 50% reduction in the occurrence of damage to baggage and the lining of the baggage compartments and a 3% reduction in the number of baggage handlers required in the operation. *Johansen (1995)* also claimed a $US 2 million saving over the first 3 years of operation of 17 B737 aircraft with the system installed. If these results are what can be expected, the slow rate of adoption of these systems by the industry may change. One would hope that as more airlines do introduce these systems, they will also publish their experience.

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There is also little doubt that the weight of the baggage required to be lifted by baggage handlers is a major factor in injury causation. Some previous authors (eg *ARTEX (1980), Dell (1994) and Bérubé (1996)*) have identified this and urged that industry limitations on baggage weight need to be enforced. It is of interest that the majority of respondents in this study also felt there was a need to enforce the pre-existing industry limits.

Unfortunately, commercial pressure in this area of airline operations often far out weighs the injury prevention considerations. At a meeting of the Ergonomics Sub-committee of the International Air Transport Executive of the National Safety Council of America at Brussels Belgium on May 5, 1995, which was chaired by the writer, the majority of attendees felt that many airline commercial department managers and supervisors would turn a blind eye to the increased injury risk to baggage handlers exposed to heavy baggage, rather than refuse to uplift a passenger's heavy bag or put the passenger to the inconvenience of re-packing their bag to reduce the weight.

Few airlines have attempted to address this difficult matter. Among those who have are Qantas, Air New Zealand, Ansett Australia and Ansett New Zealand. These airlines have procedures in place intended to limit baggage weight below 32kg, the pre-existing notional industry weight limit.

However, this Australasian attempt at using passenger education programs to tackle the heavy baggage issue has been one of mixed success. Posters and warning material at check-in locations (see Figure 6) have certainly elevated the profile of the issue, but has had little or no impact on the frequency of heavy baggage being presented to the airlines for uplift. Control of the heavy baggage risk continues to rely on compliance with baggage acceptance procedures at check-in locations to ensure baggage over 32Kg is re-packed prior to check-in.

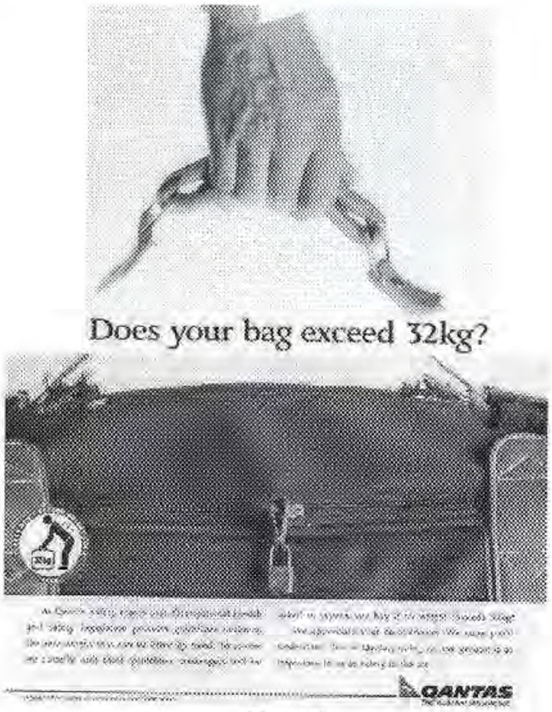

Figure 6
Heavy Baggage Advertisement to Passengers of Qantas Airways

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Also, it must be recognised that if an industry limit was to be set based on injury prevention criteria alone, then that standard would probably be closer to 16 to 20Kg, above which the risk of back injury increases significantly (see for example *Occupational Health and Safety Authority (1988)*). Doubtless, the industry would have extreme difficulty introducing such a limit since worldwide agreement would be very difficult to achieve. Also, any country or airline who attempted to introduce a limit ahead of the rest of the world would be placed at a considerable commercial disadvantage.

It is doubtful that heavy baggage in the airline industry will be removed as an injury causation factor without complete redesign of the existing manual handling tasks, or without the combined positive intervention of the various OH&S Regulators worldwide.

The juxtaposed responses to the question on use of back belts in this study is consistent with the findings of *Perkins and Bloswick (1995)*, who concluded that *"The impact of back belts on the prevention of back injuries due to manual material handling remains unclear"* and *"There is no clear evidence that back belts reduce the incidence or severity of back injuries"*. Similar conclusions were also made by *NIOSH (1994[2])* who criticised the unscientific methodologies of many earlier studies into back support belts as a possible injury prevention tool.

There is a clear bias of some authors (eg *Congleton J. et al (1993)* and *McGill S. (1993)*) away from use of back support belts in the prevention role. This is no doubt due to the emphasis in modern OH&S teaching of application of the hierarchy of hazard controls *(Dept. of Labour (1990))*. This author believes that until adequate permanent engineering controls are developed in the baggage handler back injury area, any control measure, even one on the low end of the hierarchy, is better than no control measure. Accordingly, it is a pity that researchers in the back support area have been unable or unwilling to undertake studies with sufficient scientific rigour to prove one way or the other, if back support belts could be used as a prevention tool, even as a short term solution. The baggage handler back injury problem is begging for a short, as well as long term solution.

In an operation relying heavily on manual handling such as airline baggage handling, it is not unexpected that many airlines have placed considerable emphasis in the past on back care training, as was found in this study. However, this author believes that if back care training has been in use in the airlines, as the Respondents indicate, and the back injury rates have not appreciably altered during the 3 years of this study, then additional back care training is unlikely to have a positive effect on injury occurrence. Not withstanding, 10 of the Respondents in this study felt better training was a viable option, although there would clearly be the need to find different training solutions to those applied in the past.

There may be several reasons for the apparently low success rate with use of ground equipment. As *Dell (1994)* suggested, existing airline ground equipment was designed to solve the volumetric problems associated with moving large amounts of passenger baggage to and from the passenger jet aircraft. Unfortunately, nearly all current airport baggage handling systems and ground equipment still require manual stacking and transfer of baggage from one part of the system to the next (see Figure 7). Another reason existing ground equipment may not contribute to injury prevention, is its generally poor level of maintenance in many airlines. Manual handling tasks associated with pushing and pulling baggage containers and pallets were a significant injury risk when equipment was broken or otherwise unserviceable. *"There is no doubt the industry needs to make wholesale improvements to baggage transfer systems maintenance. Airlines need to ensure that similar priority is given to maintenance of loading equipment as is afforded to other aircraft systems" (Dell (1994))*.

The design of airport terminal facilities provided for baggage handling functions is another factor in injury causation. There is no doubt that state of the art baggage sortation systems today, do not take manual handling injury risk into consideration other than by a very rudimentary ergonomic compromise. Hi-tech computerised systems deliver baggage to the location where the load for particular flights are being handled, but leave the actual loading and stacking tasks to manual handling. The new systems at Denver Stapleton, Sydney International, Brisbane International, Melbourne International and Wellington

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are examples. With these systems, the design of conveyor belts at the worker interface uses average worker heights and reach distances to try to cope with the ergonomic problems presented.

Unfortunately, this is not likely to be an easy matter to resolve. Not only is there the difficulty of designing adequate mechanical assistance devices to load baggage containers and barrows, there is a definite reluctance of airport designers and builders to give the matter the credence it deserves.

Figure 7
Loading of Containers from the Delivery Belt in the Baggage Room

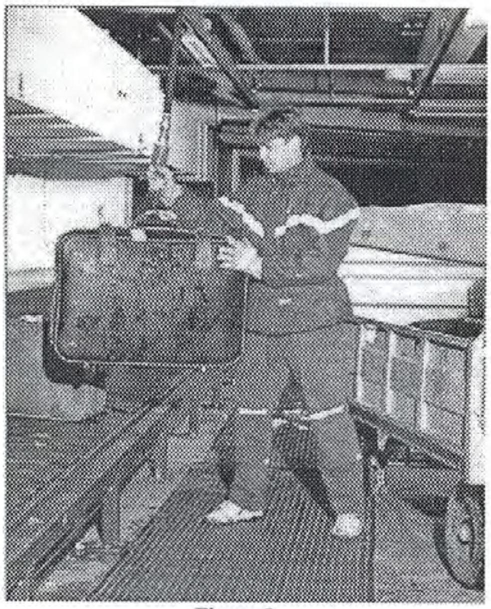

Figure 8
The AirGro *"ErGoBag"* Mechanical Assistance Device

At an Australian airline industry meeting with project officers of an airport authority in 1996, specifically to discuss design aspects of the then new Melbourne International baggage sortation system, project engineers were bemused even at the concept of making the geometry of delivery belts and container heights fully adjustable to optimise the ergonomic advantage for all individuals. The idea of providing mechanical lifting aids or automating the manual handling tasks was treated as if in the realms of science fiction. There are some systems available, however. Figure 8 shows one such device available from European manufacturer *AirGro*. Unfortunately, their adoption by airport designers is few and far between.

Airline safety professionals clearly have a difficult task ahead to make in-roads into this problem. However, unless design engineers are convinced of the seriousness of the baggage handling injury issue, they will continue to construct these critical manual handling workplaces from concrete and ignore the basic ergonomic needs of all but the average proportioned individual baggage handler.

One area of concern highlighted during the study was the difficulty some safety professionals had in quantifying the costs of back injuries and measuring the benefits of some of the supposed injury control measures. In fact, four airline safety professionals who did not complete the questionnaire, subsequently advised that their airlines had no idea of the extent of the problem and could not even identify what back injury costs were being incurred. In future, if safety professionals cannot support their efforts with basic business measures, such as cost, then it is highly unlikely that any effort to eliminate injuries in airline ground operations will be taken seriously.

CONCLUSION

LTFRs calculated from the data from the survey of safety professionals suggest that the instance of baggage handler back injuries was almost constant over the 3 years 1992 to 1994. Little comfort may be taken in the fact that there does not appear to have been a worsening trend, since neither was the trend improving and the back injury rates revealed in this study of airline industry baggage handlers were over 40 times worse than world's best practise.

The survey showed that on average, over $US 21.0 million was lost per annum due to baggage handler back injuries in only 16 organisations. Also, approximately 8.5% of baggage handlers suffered back injuries each year of the study period.

Accordingly, there is little doubt that the industry must find real and long term solutions to the causation of baggage handler back injuries.

The key injury prevention findings of this study were:

1. The need for re-design of baggage handling systems, including aircraft cargo compartments, ground equipment and airport terminal facilities to reduce or eliminate manual handling risks. A design solution must be developed for each and every manual handling task currently required to be carried out by baggage handlers.

2. Airlines need to ensure the serviceability of ground equipment and aircraft loading systems are maintained to a high standard, since the risk of injury to baggage handlers increases significantly when required to manually handle the heavier loads that were intended to be moved by the failed equipment.

3. As an interim, until design solutions are available, the need for limitation to be placed on baggage and cargo weights accepted by airlines, and a means to enforce such limits.

The support and commitment of the aircraft and ground equipment manufacturers, who will be required to take much of the remedial design action in the long term, will surely be jeopardised without accurate injury cost data from a broad airline industry base. Industry safety professionals must apply pressure to their organisations, to ensure that the real costs of injuries are recorded. Without such information, it is unlikely the manufacturers will take any further action.

Airlines who have introduced narrow body in-plane systems, such as *"Sliding Carpet"*, should make the results of their experience available to others in the industry.

There needs to be some unbiased research into whether back support belts may, or may not, provide a part solution. While no comprehensive design solutions exist, back support belts may be a useful short term measure. Presently, there is insufficient reliable scientific data for the industry to make a positive decision in this area.

This author believes that if the legislative requirements to provide safe work places, or the moral duty of care to protect the well being of employees, are not incentive enough, then the ongoing high costs of back injuries should alone dictate the need for change.

Occupational Health and Safety Professionals in the aviation industry, aircraft and ground equipment manufacturers, aviation industry associations and even the OH&S Regulators, all have an obligation to take up the challenge to address the baggage handler injury issue. There is a need to seek real solutions to the problem, address aircraft and ground equipment design and serviceability, and develop more realistic international baggage and cargo weight and size standards. If the industry doesn't achieve a satisfactory result, the labour force will likely impose sanctions which will be far less palatable and more expensive than any solutions the engineers and/or safety professionals may consider, however complex and hi-tech they may be (*Dell 1994*).

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APPENDIX NO. 21:
REFEREED PAPER: FLIGHT SAFETY FOUNDATION – *"SURVEY OF AIRLINE BAGGAGE HANDLERS SUGGESTS METHODS TO PREVENT BACK INJURIES"*

FLIGHT SAFETY FOUNDATION
Airport Operations
Vol. 24 No. 5 *For Everyone Concerned with the Safety of Flight* September–October 1998

Survey of Airline Baggage Handlers Suggests Methods to Prevent Back Injuries

A recent opinion survey of 156 baggage handlers explored the causes and prevention of back injuries in their occupation. Most of the participants, employed by 10 airlines and two ground-handling companies, said that manual handling and stacking of baggage within the baggage compartments of narrow-body aircraft pose the highest risk of back injury.

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Geoff Dell
Protocol Safety Management

Advances in ergonomics (human engineering) continually improve the flight decks and cabins of transport-category aircraft, but some researchers believe that improvements should be made in areas below the cabin floors to help prevent back injuries among baggage handlers.

This article summarizes the opinions of 156 baggage handlers from 10 airlines and two ground handling companies worldwide on tasks associated with back-injury risk, identifies elements of the baggage-handling system and equipment that are believed to present significant manual-handling problems, and suggests appropriate solutions. *Manual handling* refers to physical baggage movement in general, including tasks such as loading, moving baggage within a compartment, stacking, unloading and transferring. *Stacking* refers to placing bags on top of one another to fill the baggage compartment as bags are loaded into the aircraft. The injury risks during stacking have been studied because manual lifting of bags to various heights is required, sometimes to the height of the baggage handler's head.

Baggage handlers from the following organizations were interviewed: Aerolíneas Argentinas, Argentina; Austral Líneas Aéreas, Argentina; Delta Air Lines, Germany; Delta Air Lines, U.S.; Lufthansa German Airlines, Germany; Northwest Airlines, U.S.; Midwest Express Airlines, U.S.; Qantas Airways, Australia; Scandinavian Airlines System, Sweden; Service Master, U.S.; and CLT Aviation, U.S.

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The study selected participants randomly at each organization, and the interviewers used the following set of questions:

- How long have you worked as a baggage handler?
- What are your age and gender?
- Have you personally experienced a back injury?
- How often have you experienced back pain?
- Are baggage handlers in your organization required to lift bags or cargo items that weigh more than 70 pounds (32 kilograms)? (This industry standard defines the weight of a piece of passenger baggage for the purpose of charging excess-baggage fees.)
- From a list of five baggage-handler workplace locations, which do you consider the most likely and the least likely to cause back injuries?
- From a list of 12 manual-handling tasks routinely performed by baggage handlers, which five tasks do you consider the most likely to cause back injuries?

- What back-injury-control measures have been adopted by your company?
- What measures do you believe would be necessary to reduce back injuries among baggage handlers?

From 1992 to 1994, 25 percent of compensation claims filed by workers in Victoria, Australia, recorded back injuries as the most serious ailment suffered by the claimants.[1] In 1996, Workcover New South Wales in Australia reported that back injuries were 30 percent of all the state's workplace injuries in the period from 1993 to 1995.[2]

Studies have been documenting the workplace back-injury problem for more than 10 years. In 1987, the Workers Compensation Board of Ontario, Canada, said that back injuries accounted for 27 percent of all lost-time compensation claims.[3] A 1993 study of Swedish male workers with back ailments[4] and a 1986 study of nurses in England[5] suggested that 80 percent of workers experience lower-back ailments during their working life.

In 1994, 20 percent of all injuries and illnesses in U.S. workplaces were back injuries, and these injuries cost more than US$20 billion, said a report by the U.S. National Institute of Occupational Safety and Health (NIOSH).[6]

For nearly 20 years, back-injury problems among airline baggage handlers[7] have been a subject of academic research. The International Air Transport Executive of the National Safety Council of America (ARTEX) was among the earliest investigators of baggage-handler back injuries. In a 1981 report, ARTEX said that 340 baggage-handler back injuries had occurred among 10 airlines in 1977.[8] ARTEX also said that loading or unloading of narrow-body aircraft[9] was involved in 85 percent of the injuries.

A 1997 study[10] found that back injuries to baggage handlers at 15 airlines and one ground-handling company cost an average of $21 million per year during the period from 1992 to 1994, that 8.5 percent of baggage handlers suffered back injuries each year and that the average annual lost-time back-injury[11] frequency rate (LTFR) during the period was 41.5 (per million hours worked). Airline-safety professionals surveyed in this study also rated loading and unloading of narrow-body aircraft as the greatest back-injury causation risk.

Of the 156 baggage handlers surveyed in this study, 148 were male and eight were female. The participants had baggage-handling experience ranging from six months to 32 years, with an average of 10.6 years of experience. The ages of participants ranged from 17 years to 62 years, with an average age of 36 years.

In the study, 110 (70 percent) of these baggage handlers believed that the "narrow-body-aircraft baggage compartment" was the workplace location likely to cause the most back injuries (Table 1). Significantly lower percentages of participants believed that other workplace locations were likely to cause the most back injuries. "Baggage check-in" was the second-most-common response to this question (13 participants), followed by "outside the aircraft on the tarmac" (11 participants), "baggage sorting rooms" (nine participants) and "inside wide-body-aircraft bulk holds" (nine participants).

Table 1
Baggage-handler Opinions on Locations Likely to Cause the Most Back Injuries

Workplace Location	Number	Percent
Inside narrow-body-aircraft baggage compartments	110	(70)
Baggage check-in areas	13	(8)
Outside the aircraft on the tarmac	11	(7)
Baggage-sorting rooms	9	(6)
Inside wide-body-aircraft bulk holds	9	(6)
No response	4	(3)
Total	**156**	**100**

Source: Geoff Dell

The bulk hold is the rearmost baggage-and-cargo compartment in a wide-body aircraft, accessed by a separate door in the rear fuselage. Baggage handlers transfer baggage and cargo into the bulk hold using a mobile-belt-loader vehicle, a method similar to loading a narrow-body-aircraft baggage compartment. Baggage handlers stack bags manually inside bulk holds. In some wide-body aircraft, the floor-to-ceiling heights in the rear of the bulk hold (the area immediately forward of the aft bulkhead) are significantly lower than the floor-to-ceiling heights in the baggage compartments of narrow-body aircraft.

Concerning heavy baggage, 139 of these baggage handlers (89 percent) said that they were required to lift pieces of baggage that weighed more than 70 pounds, and 141 participants (90 percent) said that they believed that pieces of baggage heavier than 70 pounds created a significant injury risk.

Table 2, page 3 shows the baggage handlers' responses to questions about which manual-handling tasks are likely to cause back injuries.

Two baggage-handling tasks related to narrow-body aircraft — pushing bags from doorways into baggage compartments of narrow-body aircraft and stacking bags inside baggage compartments of narrow-body aircraft — were believed by the most participants (136 participants and 135 participants, respectively) to be likely to cause back injuries. Baggage handlers believed that "transferring bags from baggage trailers directly into the aircraft" was the task next most likely to cause back injuries (131 participants), followed by "pushing and pulling loaded trailers" (129 participants).

Table 2
Baggage-handler Opinions* on Manual-handling Tasks Likely to Cause Back Injuries

	Back-injury Likelihood					
Manual-handling Task	Likely	Percent	Unlikely	Percent	No Response	Percent
Pushing bags from doorways into baggage compartments of narrow-body aircraft	136	(87)	18	(12)	2	(1)
Stacking bags inside baggage compartments of narrow-body aircraft	135	(87)	16	(10)	5	(3)
Transferring bags from trailers directly into aircraft	131	(84)	21	(13)	4	(3)
Pushing and pulling loaded trailers	129	(83)	25	(16)	2	(1)
Pushing containers inside wide-body aircraft (with loading systems out of service)	118	(76)	27	(17)	11	(7)
Stacking baggage inside wide-body-aircraft bulk holds	113	(73)	30	(19)	13	(8)
Loading bags onto trailers in baggage rooms	107	(69)	47	(30)	2	(1)
Loading containers in baggage rooms	104	(67)	42	(27)	10	(6)
Transferring bags from trailers to mobile belts	103	(66)	49	(31)	4	(3)
Unloading containers in baggage rooms	101	(65)	44	(28)	11	(7)
Unloading trailers in baggage rooms	93	(60)	61	(39)	2	(1)
Lifting baggage on and off conveyors	69	(44)	83	(53)	4	(3)

* A total of 156 baggage handlers participated in this opinion survey.

Source: Geoff Dell

"Pushing containers inside wide-body aircraft when the mechanical-loading systems are unserviceable [out of service]" was believed to be likely to cause back injuries by 118 participants (76 percent). "Stacking baggage inside wide-body-aircraft bulk holds" was considered to be a back-injury risk by 113 of the baggage handlers (73 percent).

Eighty-three of the baggage handlers (53 percent) believed that lifting baggage on and off conveyors was the only manual-handling task that did not present a risk of back injuries.

Seventy-two of the participants (46 percent) said that they had experienced a back injury while handling baggage (Table 3). Of those, 40 baggage handlers (56 percent) said that their back injuries reduced their ability to work, and 43 baggage handlers (60 percent) said that the injury had recurred at least once since the first injury.

In response to the question "How often do you experience back pain when handling baggage?" 110 baggage handlers (71 percent) said that they had experienced back pain more than once. Twenty-seven participants (17 percent) said that they had back pain daily, 24 participants (15 percent) said that they had back pain weekly, 18 participants (12 percent) said that they had back pain monthly, and 41 participants (26 percent) said that they seldom had back pain.

When questioned about the design of baggage-sorting rooms, 88 participants (56 percent) said that they believed that efficient design of baggage-sorting rooms made their job easier. The survey found that the heights of conveyor belts were considered adequate by 82 baggage handlers (52 percent).

Fifty-three baggage handlers (34 percent) said that their airlines have stacking systems installed in narrow-body aircraft. Of those participants, 47 (89 percent) said that the system made baggage handling easier and reduced their exposure to back injuries. All 53 of these baggage handlers said that they preferred loading aircraft fitted with stacking systems to loading aircraft without stacking systems.

Table 3
Baggage-handler Opinions* on Personal Back-injury Experience at Work

Question	Yes	Percent	No	Percent	No Response	Percent	Total
Have you personally experienced a back injury while handling baggage?	72	(46)	84	(54)	0	(0)	156
Has the back injury reduced your ability to handle baggage?	40	(56)	32	(44)	0	(0)	72
Has the injury recurred since the first injury?	43	(60)	29	(40)	0	(0)	72

* A total of 156 baggage handlers participated in this opinion survey.
Note: Percentages may not total 100 because of rounding.

Source: Geoff Dell

Table 4 shows the baggage handlers' responses concerning possible engineering-redesign solutions to the back-injury problem.

The development of in-plane baggage-stacking and cargo-stacking systems was the engineering-redesign solution recommended by the largest number of participants. A total of 122 baggage handlers (78 percent) said that this is a viable method of reducing the risk of back injury in aircraft loading. The redesign of baggage-handling systems to reduce back-injury risk was supported by 111 baggage handlers (71 percent). Although most participants supported all engineering-redesign solutions, 93 participants (60 percent) supported the provision of mechanical-assistance devices for lifting baggage, 89 participants (57 percent) supported the introduction of robotics to eliminate manual baggage handling and 78 participants (50 percent) supported aircraft baggage-compartment redesign.

Table 5 shows details of the baggage handlers' opinions about possible administrative and procedural solutions to prevent back injuries.

The most highly ranked procedural intervention — and the most-often-recommended solution in the survey — was introducing tags marked HEAVY to alert baggage handlers to the possible increased injury risk presented by the labeled pieces. The survey showed that 140 (90 percent) supported this intervention and 138 participants (88 percent) supported "baggage-handler training" as a potential solution. "Improve maintenance of baggage-handling equipment" received 121 positive responses (78 percent) as a preferred solution. "Introduce warm-up exercises" received 98 positive responses (63 percent), and "improve the quality of supervision" received 67 positive responses (43 percent).

Because some of the airlines and baggage-handling companies required or permitted the use of back-support belts

Table 4
Baggage-handler Opinions* on Engineering-redesign Strategies to Prevent Back Injury

Strategies	Yes	Percent	No	Percent	No Response	Percent
Develop in-plane baggage-stacking and cargo-stacking systems	122	(78)	27	(17)	7	(4)
Redesign baggage-handling systems to reduce back-injury risk	111	(71)	41	(26)	4	(3)
Provide mechanical-assistance devices for lifting baggage	93	(60)	49	(31)	14	(9)
Introduce robotics to eliminate manual baggage handling	89	(57)	60	(38)	7	(4)
Redesign aircraft baggage compartments	78	(50)	69	(44)	9	(6)

* A total of 156 baggage handlers participated in this opinion survey.
Note: Percentages may not total 100 because of rounding.
Source: Geoff Dell

Table 5
Baggage-handler Opinions* on Procedural and Administrative Strategies to Prevent Back Injuries

Strategies	Yes	Percent	No	Percent	No Response	Percent
Place tags marked HEAVY on heavy bags to alert handlers	140	(90)	3	(2)	13	(8)
Improve baggage-handler training	138	(88)	14	(9)	4	(3)
Improve maintenance of baggage-handling equipment	121	(78)	27	(17)	8	(5)
Improve baggage-acceptance and cargo-acceptance procedures	120	(77)	23	(15)	13	(8)
Improve staff scheduling to meet work demand	119	(76)	31	(20)	6	(4)
Educate the public concerning baggage-handler back-injury risk	118	(76)	26	(17)	12	(8)
Enforce a lower baggage-weight limit	114	(73)	28	(18)	14	(9)
Slow down the baggage-handling process	104	(67)	48	(31)	4	(3)
Require passengers to repack heavy bags to reduce weight	101	(65)	42	(27)	13	(8)
Introduce back-support belts	100	(64)	47	(30)	9	(6)
Introduce warm-up exercises	98	(63)	52	(33)	6	(4)
Improve the quality of supervision	67	(43)	82	(53)	7	(4)

* A total of 156 baggage handlers participated in this opinion survey.
Note: Percentages may not total 100 because of rounding.
Source: Geoff Dell

in the past, the interviewers asked participants a number of questions about the use of back-support belts. Table 6 shows the responses.

Sixty-three of the participants (40 percent) said that they had worn back-support belts, and 10 of these baggage handlers (6 percent) said that they had suffered a back injury while wearing a back-support belt. Ninety-three of the baggage handlers (60 percent) believed that back-support belts improve the wearer's ability to perform baggage-handling tasks. Ninety-four participants (60 percent) believed that back-support belts help prevent lost-time back injuries, and 86 participants (55 percent) believed that back supports should be worn for all lifting tasks. Thirteen of the baggage handlers (8 percent) believed that wearing back-support belts would make lifting-technique training unnecessary.

Table 7 shows that the majority of baggage handlers supported the use of lifting-technique training to reduce the risks of back injury in baggage-handling tasks. In the survey, 145 of the participants (93 percent) said that training should include techniques for lifting with restricted postures in confined spaces. The responses of 129 participants (83 percent) said that back-care training would help prevent lost-time back injuries, and 125 participants (80 percent) believed that training would enhance baggage handlers' ability to perform handling tasks.

Several researchers have said that the ergonomic design of narrow-body-aircraft cargo compartments has placed significant limitations on baggage-handler working postures and has increased the risk of injury.[12] Baggage compartments in narrow-body aircraft such as the Boeing 737, McDonnell Douglas DC-9, British Aerospace BAe 146 and Fokker 100 provide space for stacking baggage and cargo, but there are no machines available to assist with stacking baggage inside narrow-body aircraft. As a result, manual baggage handling — typically using a restricted working posture — has been

Table 6
Baggage-handler Opinions* on Back-support Belts

Question	Yes	Percent	No	Percent	No Response	Percent
Have you personally worn a back-support belt to help prevent back injuries?	63	(40)	90	(58)	3	(2)
Have you experienced a back injury while wearing a back-support belt?	10	(6)	123	(79)	23	(15)
Do back-support belts improve the wearer's ability to perform baggage-handling tasks?	93	(60)	52	(33)	11	(7)
Do back-support belts help prevent lost-time back injuries?	94	(60)	52	(33)	10	(6)
Should back-support belts be worn for all lifting tasks?	86	(55)	60	(38)	10	(6)
Do back-support belts make lifting-technique training unnecessary?	13	(8)	133	(85)	10	(6)
If you wear a back-support belt at work, must you wear it when lifting at home?	66	(42)	79	(51)	10	(6)

* A total of 156 baggage handlers participated in this opinion survey.
Note: Percentages may not total 100 because of rounding.
Source: Geoff Dell

Table 7
Baggage-handler Opinions* on Lifting-technique Training to Prevent Back Injuries

Question	Yes	Percent	No	Percent	No Response	Percent
Should training include techniques for lifting with restricted postures in confined spaces?	145	(93)	9	(6)	2	(1)
Will back-care training help prevent lost-time back injuries?	129	(83)	25	(16)	2	(1)
Does back-care training improve baggage handlers' ability to perform handling tasks?	125	(80)	30	(19)	1	(1)
Should warm-up exercises be part of baggage handlers' daily routine?	106	(68)	48	(31)	2	(1)
Does lifting-technique training (back straight, knees bent) benefit baggage handlers?	104	(67)	48	(31)	4	(3)

* A total of 156 baggage handlers participated in this opinion survey.
Note: Percentages may not total 100 because of rounding.
Source: Geoff Dell

Action Urged to Prevent Baggage-handler Back Injuries

Since the early 1980s, several organizations have shown interest in preventing back injuries among airline baggage handlers. Airports, baggage-sorting systems and ground-equipment designs are all linked and dependent on aircraft-system design. Aircraft manufacturers will be the key for long-term design solutions to the risk of back injuries among baggage handlers.

Nevertheless, some short-term solutions should be implemented quickly based on the consensus of researchers and current technology. Airlines that already have retrofitted semiautomated baggage-handling systems in narrow-body aircraft should share their experience and data with other airlines in the interest of back-injury prevention. Air-transport-industry associations should play a leading role in setting global standards that account for the known problems in manually handling airline baggage. An industry-wide solution should be developed based on the consensus position about heavy baggage, for example. Reducing the weight of individual pieces of baggage handled by baggage handlers may be the only effective method to reduce exposure to this back-injury risk. A related solution is for all airlines to label baggage and cargo with accurate weights and alert labels. This would permit baggage handlers to prepare for each lift and to assess the injury risks of handling each item.

Past reliance on designing airport systems for the dimensions of the physically "average" baggage handler should be replaced by solutions that provide ergonomic advantages for all system users. Baggage-handling-system design has focused on solutions to the volumetric problems of baggage transfer and sorting. Relatively few ergonomic principles — with the exception of integration of average height and reach distances — have been applied.

Ground equipment and aircraft-loading systems not only should be provided, but these systems also should be maintained to a high standard. When equipment is out of service, the risk of injury to baggage handlers increases significantly because people manually handle loads that should be moved by machines. For injury prevention within the current work environment, there also is a need to provide better lifting-technique training for baggage handlers, and to improve serviceability (time in service) of baggage-handling systems and related equipment.

Although back-support belts are low on the hierarchy of hazard controls, the current lack of clearly effective injury-prevention measures suggests that all control measures should be considered. The hierarchy theory suggests that personal protective equipment, such as back-support belts, is the least effective injury-prevention measure compared to engineering solutions and other workplace-intervention solutions. (See Victorian Department of Labor. *Hazard Control*. Melbourne, Australia: Labor Share Program, Victorian Department of Labor, 1990.) Back-support belts should be evaluated using sound scientific methods to demonstrate whether or not the belts are an effective injury-prevention tool for baggage handlers.

Development and enforcement of occupational health and safety regulations, using the latest data, also should be improved. If engineering solutions cannot be found for the manual-handling tasks associated with passenger baggage and cargo, occupational health and safety regulations should require airlines to find other methods.♦

— Geoff Dell

the only option available to load and unload narrow-body aircraft. Baggage handlers presently use mechanical-assistance devices in baggage-sorting rooms of a few airports.

A majority of the 156 baggage handlers surveyed in this study — 135 participants (87 percent) — also said that stacking baggage inside narrow-body aircraft was one of the tasks most likely to cause back injuries.

The ergonomic problems of narrow-body-aircraft baggage compartments have been identified and quantified relatively recently. Nevertheless, some workplace-safety researchers believe that aircraft-design processes should take into account the incidence and the cost of injuries to baggage handlers. These researchers have said that baggage-handling solutions should receive increased attention among airline-specified performance criteria such as range, payload, fuel economy and overall operating cost.

One researcher, for example, said, "There will have to be airline-industry consensus before the aircraft manufacturers will carry out design changes to their aircraft."[13]

Forty-four percent of the baggage handlers said that engineering redesign of baggage compartments would be a potential method to prevent back injuries. This response may reflect an assumption by these baggage handlers that changes in aircraft baggage-compartment designs are unlikely to occur.

Some airlines have retrofitted semiautomated loading systems in the baggage compartments of current models of narrow-body aircraft. These loading systems provide a movable wall that can be positioned near the baggage-compartment door. The movable wall typically enables baggage handlers to stack all bags adjacent to the doorway. Each time a stack of bags adjacent to the doorway reaches the ceiling, the baggage handler mechanically moves the stack farther into the baggage compartment. The stack-and-move operation continues until the movable wall meets the inner bulkhead and the compartment is full. Such systems eliminate the need for baggage handlers to move bags manually along the length of the cargo compartment. Nevertheless, these systems require baggage handlers to stack bags in the baggage compartment.

Although not yet in wide use, these types of automated systems have been installed by some airlines, and their contribution to safety has been encouraging. A 1995 study, for example, found a 25 percent reduction in baggage-handler sick-leave rates.[14] This study also estimated cost savings of $2 million during the first three years of operation of 17 B-737 aircraft with one type of loading system.

There has been a consensus among some studies that the weight of passenger baggage has been a major injury-causation factor.[15] Ninety percent of the participants in a 1997 survey said that heavy passenger baggage is a significant injury risk.[16] Weight reduction of individual baggage has been required by occupational health and safety legislation in Victoria, Australia, to reduce worker exposure to injuries.[17]

Airlines that have introduced baggage-weight restrictions based on occupational health and safety recommendations — such as Qantas, Ansett Australia and Air New Zealand — have had mixed results, said the 1997 study.[18] Because there has not been widespread adoption of baggage-weight restrictions among all airlines, the airlines that introduce weight restrictions have a competitive disadvantage. Passengers who are permitted to check heavy baggage on one airline react negatively if asked by another airline to repack baggage to reduce the weight of each piece.

The survey found that approximately half of the participants had used back-support belts. Many of the baggage handlers in this group, however, said that back-support belts were part of the overall solution.

Research on the use of back-support belts as injury-prevention devices has provided mixed conclusions about the effectiveness of the belts. In 1995, two researchers said, "The impact of back belts on the prevention of back injuries due to manual material handling remains unclear. ... There is no clear evidence that back belts reduce the incidence or severity of back injuries."[19] Some studies said that the data do not show that back-support belts have been effective in injury prevention.[20]

NIOSH said in 1994 that many earlier studies of back-support belts did not follow accepted scientific methods, and therefore cannot be used either to support or to refute claims about the effectiveness of back-support belts in injury reduction.[21] More recent studies based on comparisons of back-injury rates have not provided conclusive evidence for the effectiveness of back-support belts, NIOSH said in 1997.[22] The institute therefore does not recommend the use of back-support belts to prevent injuries among workers who never have been injured (NIOSH has not evaluated the use of back-support belts as a medical treatment during rehabilitation from injury). The consensus of researchers has been that more scientifically rigorous research should be conducted to determine the effectiveness of back-support belts in airline baggage handling.♦

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APPENDIX No. 22
MICHIGAN PROGRAM OUTPUT DATA

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task:	gender:	height:	weight:	r. vert. force angle:	r. horiz. force angle:	r. forearm vert. angle:	r. forearm horiz. angle:	r. upper arm vert. angle:	r. upper arm horiz. angle:	r. upper leg angle:	r. lower leg angle:	l. vert. force angle:	l. horiz. force angle:	l. forearm vert. angle:	l. forearm horiz. angle:	l. upper arm vert. angle:	l. upper arm horiz. angle:	l. upper leg angle:	l. lower leg angle:	torso lat. bend angle:	torso flex angle:	torso ax. rotat. angle:	right force magnitude :	left force magnitude :	L5 S1 Disc Compression:	L5 S1 Disc compression std dev:	moment @ right elbow:	% capable right elbow:	@ right shoulder (humeral	capable right shoulder	@ right shoulder (fwd/bkwd	right shoulder (fwd/bkwd	right shoulder (adduc./abduc .):	right shoulder (adduc./abc
Subject 1 mpg1 a Ace Left	Male	177	75.2	-88	117	19	-123	2	-135	157	-7	-90	90	34	-33	15	-31	157	-7	-16	107	90	157	157	3327.34	731.839	-44.0912	85	-10.6209	100	-6.87323	100	-113.335	
Subject1 mpg1 b sc left	Male	177	75.2	-88	117	-8	-104	14	160	157	-7	-90	90	42	-25	17	-33	157	-7	-3	118	75	157	157	3023.48	629.709	11.6265	100	-54.7065	4	31.8546	96	-44.3324	8
Subject1 mpg1 c ns left	Male	177	75.2	-88	148	31	-110	-21	-171	157	-7	-87	125	46	-16	1	-56	157	-7	-6	126	86	157	157	3777.07	818.748	-28.2741	99	-38.5626	91	26.9548	98	-78.4792	3
Subject1 mpg2 a ace centre	Male	177	75.2	-89	-143	20	167	-12	140	118	-7	-88	-146	44	59	1	25	118	-7	-40	82	55	157	157	1221.11	95.3446	-39.3326	93	-24.1433	98	31.8243	96	-102.755	
Subject1 mpg2 b sc centre	Male	177	75.2	-89	-143	34	171	-14	147	157	-7	-88	-146	69	17	-40	58	157	-7	-6	81	22	157	157	2695.81	175.846	-40.9372	94	-19.1956	99	-19.0967	99	-100.847	
Subject1 mpg2 c nsc centre	Male	177	75.2	-89	-143	35	169	6	149	157	-7	-88	-146	12	44	20	2	157	-7	0	87	53	157	157	1907.92	116.789	-36.9843	95	-16.2604	99	-8.23141	99	-104.613	
Subject1 mpg3 a ace right	Male	177	75.2	-89	-143	17	142	-15	153	125	-7	-88	-146	15	89	-8	13	125	-7	-12	40	13	157	157	5568.2	426.141	-51.6022	74	9.54272	99	-79.972	68	-79.2034	3
Subject1 mpg3 b sc right	Male	177	75.2	-89	-143	12	160	-10	134	115	-7	-88	-146	19	85	-12	0	115	-7	-35	55	16	157	157	3977.75	313.916	-34.6662	95	-24.3037	98	0	100	-110.309	
Subject1 mpg3 c ns right	Male	177	75.2	-89	-143	17	150	-16	144	100	-7	-88	-146	40	77	-33	-5	100	-7	-8	53	20	157	157	3753.39	298.152	-53.3429	72	-5.9387	100	-57.8611	91	-96.9918	
Subject2 mpg4 a ace left	Male	177	75.2	-89	127	5	159	5	115	115	-7	-88	-157	5	62	5	30	115	-7	-29	80	41	157	157	2430.86	190.617	1.49304	100	-39.2045	32	43.56	85	-92.1629	
Subject2 mpg4 b sc left	Male	177	75.2	-89	127	14	-133	2	171	130	-7	-88	-157	9	29	10	-36	130	-7	-13	75	70	157	157	616.286	27.5801	-7.60514	100	-45.524	27	-29.512	99	-87.3717	
Subject2 mpg4 c ns left	Male	177	75.2	-89	127	34	126	-34	107	105	-7	-88	-157	51	94	-8	52	105	-7	-30	63	26	157	157	4037.15	318.558	-45.5996	90	-12.8629	99	24.3768	98	-92.5503	1
Subject2 mpg5 a ace centre	Male	177	75.2	-89	127	0	117	0	90	100	-7	-88	-157	25	66	-38	50	100	-7	-25	59	37	157	157	4863.39	384.313	0	100	-25.7781	73	58.1217	50	-95.5118	
Subject2 mpg5 b sc centre	Male	177	75.2	-89	127	15	129	-16	96	110	-7	-88	-157	25	66	-38	50	110	-7	-15	75	33	157	157	3620.83	283.564	-37.0384	96	-28.8265	90	15.6729	99	-104.008	
Subject2 mpg5 c ns centre	Male	177	75.2	-89	127	32	117	16	102	150	-7	-88	-157	25	94	15	35	150	-7	12	81	33	157	157	4194.11	297.288	-34.9223	95	-12.1451	99	-26.4936	99	-102.796	
Subject2 mpg6 a ace right	Male	177	75.2	-89	127	20	107	21	61	100	-7	-88	-157	29	140	-5	64	100	-7	-18	50	20	157	157	5051.8	400.785	9.3713	99	-35.9993	10	86.9158	1	-40.1751	9
Subject2 mpg6 b sc right	Male	177	75.2	-89	127	33	131	-31	98	124	-7	-89	130	-4	94	15	57	124	-7	1	73	40	157	157	4326.2	328.472	-41.9062	94	-22.417	97	-19.5186	99	-91.3385	1
Subject2 mpg6 c ns right	Male	177	75.2	-89	127	25	134	-4	80	105	-7	-89	130	22	109	-18	37	105	-7	1	53	33	157	157	5034.4	398.514	-18.7561	99	-41.8157	18	10.2878	99	-91.0764	
Subject3 mpg7 a ace left	Male	177	75.2	-89	127	12	158	-2	116	105	-7	-88	-157	17	54	-17	40	105	-7	-23	55	41	157	157	4743.62	375.144	-15.5863	99	-37.162	44	10.0606	99	-102.233	
Subject3 mpg7 b sc left	Male	177	75.2	-89	127	22	-172	2	170	115	-7	-88	-157	22	3	6	-19	115	-7	-15	75	51	157	157	532.992	36.3536	-38.7795	93	-16.0498	99	-34.5661	98	-106.127	
Subject3 mpg7 c ns left	Male	177	75.2	-89	127	4	150	-4	81	105	-7	-88	-157	2	40	-14	53	105	-7	-14	59	26	157	157	4641.4	366.471	-6.09299	100	-52.7738	0	27.693	96	-76.5223	2
Subject3 mpg8 a ace centre	Male	177	75.2	-89	127	14	111	-6	101	100	-7	-88	-157	49	82	-32	28	100	-7	-23	49	37	157	157	5115.8	406.027	-49.1506	72	-9.64057	100	39.4607	85	-108.349	
Subject3 mpg8 b sc centre	Male	177	75.2	-89	127	30	126	-29	125	130	-7	-88	-157	-12	64	-2	32	130	-7	3	60	33	157	157	4771.65	361.749	-49.6387	85	0	100	-41.3388	97	-94.1269	1
Subject3 mpg8 c ns centre	Male	177	75.2	-89	127	43	125	-39	134	100	-7	-88	-157	31	70	-22	46	100	-7	-12	59	51	157	157	4353.81	344.378	-41.8573	94	5.09459	100	-20.3201	99	-86.4489	1
Subject3 mpg9 a ace right	Male	177	75.2	-89	127	12	164	3	90	100	-7	-88	-157	17	92	-21	54	100	-7	-11	50	31	157	157	5188.08	411.466	0	100	-53.4632	0	25.6601	96	-72.213	2
Subject3 mpg9 b sc right	Male	177	75.2	-89	127	28	132	-23	119	100	-7	-89	130	3	91	-15	58	100	-7	1	44	40	157	157	5622.27	447.197	-48.8466	83	-10.4097	99	-52.0581	93	-91.6604	
Subject3 mpg9 c ns right	Male	177	75.2	-89	127	18	137	5	98	85	-7	-89	130	32	117	-33	55	85	-7	1	53	30	157	157	5182.38	411.969	-13.2962	99	-34.0099	61	-14.4866	99	-102.381	
Subject4 mpg10 a ace left	Male	177	75.2	-89	127	12	158	-2	116	105	-7	-88	-157	17	54	-17	40	105	-7	-15	45	18	157	157	5259.4	417.722	-15.5863	99	-37.162	64	-20.0764	99	-100.729	
Subject4 mpg10 b sc left	Male	177	75.2	-89	127	27	177	-2	135	133	-7	-88	-157	46	30	-17	12	133	-7	-15	66	15	157	157	3211.82	236.032	-25.1726	99	-33.7504	91	-22.0713	99	-96.7404	
Subject4 mpg10 c ns left	Male	177	75.2	-89	127	42	-154	-5	161	133	-7	-88	-157	49	25	-24	-27	133	-7	-17	59	42	157	157	2699.14	188.651	-26.3636	99	-29.3156	95	-51.2761	94	-75.7451	2
Subject4 mpg11 a ace centre	Male	177	75.2	-89	127	14	111	-6	101	100	-7	-88	-157	49	82	-32	28	100	-7	-11	51	32	157	157	5053.11	400.669	-49.1506	72	-9.6406	100	7.00778	99	-115.112	
Subject4 mpg11 b sc centre	Male	177	75.2	-88	-149	38	179	-7	163	145	-7	-88	-157	44	8	-11	-4	145	-7	3	93	63	157	157	320.105	-7.97249	-42.0652	93	-13.1887	99	0	100	-104.427	
Subject4 mpg11 c ns centre	Male	177	75.2	-89	127	30	-176	3	180	140	-7	-88	-157	49	19	-7	-23	140	-7	-12	93	71	157	157	996.785	175.486	-48.9758	79	-3.09012	100	0	100	-110.575	
Subject4 mpg12 a ace right	Male	177	75.2	-89	127	31	157	-16	100	90	-7	-88	-157	-9	84	14	48	90	-7	-11	48	17	157	157	5374.65	427.541	-26.4952	99	-39.3387	62	-5.57059	100	-86.2089	
Subject4 mpg12 b sc right	Male	177	75.2	-89	127	32	153	7	145	140	-7	-89	130	29	82	-15	23	140	-7	-6	55	46	157	157	5047.97	374.83	-46.2738	81	-6.54104	100	-67.5279	81	-85.6508	2
Subject4 mpg12 c ns right	Male	177	75.2	-89	127	18	137	-5	98	100	-7	-89	130	12	87	-8	70	100	-7	1	63	40	157	157	4996.96	394.4	-24.9578	99	-33.9827	59	-14.3085	99	-102.274	
Subject5 mpg13 a ace left	Male	177	75.2	-89	127	9	149	-15	130	93	-7	-88	-157	2	29	-1	66	93	-7	-10	44	18	157	157	5288.12	421.527	-44.3523	86	-17.5385	99	-56.9439	90	-96.7548	
Subject5 mpg13 b sc left	Male	177	75.2	-89	127	28	-144	-8	152	140	-7	-88	-157	46	25	-12	-25	140	-7	-15	106	42	157	157	1771.29	349.787	-18.1612	99	-44.3237	73	19.7347	99	-81.0024	2
Subject5 mpg13 c ns left	Male	177	75.2	-89	127	12	-170	5	163	133	-7	-88	-157	56	40	-4	-5	133	-7	-17	104	29	157	157	1335.48	258.256	-12.7477	99	-25.0809	98	32.615	97	-105.895	
Subject5 mpg14 a ace centre	Male	177	75.2	-89	127	14	111	-6	101	90	-7	-88	-157	49	82	-32	28	90	-7	-11	41	9	157	157	5532.42	441.88	-49.1506	70	-9.64059	100	4.37051	99	-115.247	
Subject5 mpg14 b sc centre	Male	177	75.2	-88	-149	19	-174	0	125	141	-7	-88	-157	28	54	12	7	141	-7	-12	93	48	157	157	1181.47	66.4731	-8.84301	100	-47.5516	20	18.1888	99	-85.5132	1
Subject5 mpg14 c ns centre	Male	177	75.2	-89	127	16	172	9	157	120	-7	-88	-157	15	51	0	-20	120	-7	-12	60	63	157	157	2990.53	226.233	-22.6864	99	-13.9247	99	-63.3003	86	-94.31	
Subject5 mpg15 a ace right	Male	177	75.2	-89	127	21	118	-15	99	90	-7	-88	-157	49	84	-72	43	90	-7	-11	43	17	157	157	5105.54	407.818	-46.6159	83	-16.8594	99	4.92624	99	-109.377	
Subject5 mpg15 b sc right	Male	177	75.2	-89	127	31	155	-29	133	110	-7	-89	130	-23	46	0	23	110	-7	-7	41	60	157	157	4727.31	375.51	-45.8577	89	-15.718	99	-60.1027	87	-78.8605	2
Subject5 mpg15 c ns right	Male	177	75.2	-89	127	34	117	-46	83	111	-7	-89	130	11	88	-7	69	111	-7	-6	61	40	157	157	4829.62	380.587	-43.7711	93	-18.6385	99	-3.60746	100	-83.4999	2
Subject6 mpg16 a ace left	Male	177	75.2	-89	127	9	149	-15	130	100	-7	-88	-157	1	65	0	28	100	-7	-19	53	18	157	157	4864.7	385.489	-44.3523	86	-17.5385	99	-29.0615	99	-108.415	
Subject6 mpg16 b sc left	Male	177	75.2	-89	127	25	-136	-14	179	150	-7	-88	-157	37	-28	3	-36	150	-7	-9	106	82	157	157	2676.31	573.601	-31.3906	98	-34.8011	90	11.4253	99	-95.8218	
Subject6 mpg16 c ns left	Male	177	75.2	-89	127	30	164	-36	111	150	-7	-88	-157	9	37	6	59	150	-7	-2	76	30	157	157	3876.55	276.151	-37.9649	97	-31.5882	86	-30.7773	99	-76.4938	2
Subject6 mpg17 a ace centre	Male	177	75.2	-89	127	17	-176	-8	156	150	-7	-88	-157	24	8	-7	14	150	-7	-31	90	67	157	157	351.839	5.35198	-35.5308	96	-25.0114	97	14.6603	99	-107.848	
Subject6 mpg17 b sc centre	Male	177	75.2	-88	-149	-1	159	0	152	150	-7	-88	-157	22	57	-13	4	150	-7	-9	93	52	157	157	1404.05	81.5039	9.45485	99	-6.88758	100	11.525	99	-117.045	
Subject6 mpg17 c ns centre	Male	177	75.2	-89	127	32	150	-8	121	150	-7	-88	-157	25	69	19	44	150	-7	-2	82	20	157	157	3640.23	258.024	-37.6063	96	-23.1262	99	-12.5286	99	-102.486	
Subject6 mpg18 a ace right	Male	177	75.2	-89	127	8	142	-6	103	90	-7	-88	-157	3	84	-6	36	90	-7	-17	43	30	157	157	5801.36	462.349	-18.2413	99	-35.2198	52	13.5082	99	-103.851	
Subject6 mpg18 b sc right	Male	177	75.2	-89	127	12	123	-9	122	110	-7	-89	130	29	109	-42	27	110	-7	-20	69	31	157	157	3756.85	294.539	-55.6695	59	0	100	7.65391	99	-115.866	
Subject6 mpg18 c ns right	Male	177	75.2	-89	127	9	117	9	98	111	-7	-89	130	11	88	-7	79	111	-7	-6	48	24	157	157	6027.57	476.767	1.63519	100	-18.0791	97	3.34387	99	-113.82	
Subject7 mpg19 a ace left	Male	177	75.2	-89	127	18	158	-19	106	100	-7	-88	-157	6	54	3	35	100	-7	-22	54	18	157	157	4804.3	380.559	-30.1966	98	-40.1844	58	5.10088	99	-92.1225	
Subject7 mpg19 b sc left	Male	177	75.2	-89	127	40	-162	-27	119	135	-7	-88	-157	9	33	3	35	135	-7	-29	67	43	157	157	3443.66	254.466	-21.0266	99	-37.8105	68	-6.20064	100	-65.8876	4
Subject7 mpg19 c ns left	Male	177	75.2	-89	127	54	167	-23	142	150	-7	-88	-157	43	56	-28	28	150	-7	-12	76	62	157	157	3210.04	222.853	-31.4386	98	-12.6627	99	-18.1884	99	-85.3574	1
Subject7 mpg20 a ace centre	Male	177	75.2	-89	127	21	138	-16	123	135	-7	-88	-157	10	63	-19	56	135	-7	-21	55	29	157	157	5569.4	424.994	-49.2225	80	-13.1649	99	-11.0273	99	-109.72	
Subject7 mpg20 b sc centre	Male	177	75.2	-89	70	28	158	-31	132	150	-7	-88	-157	21	33	-35	39	150	-7	-9	81	38	157	157	2947.06	203.915	-45.9523	91	-18.0741	99	-17.1217	99	-96.8764	
Subject7 mpg20 c ns centre	Male	177	75.2	-89	127	31	140	-17	130	150	-7	-88	-157	17	66	-12	50	150	-7	3	82	45	157	157	3783.94	268.532	-47.9863	87	-8.00472	100	-22.639	99	-104.377	
Subject7 mpg21 a ace right	Male	177	75.2	-89	127	8	142	-6	128	105	-7	-88	-157	3	84	-6	21	105	-7	-22	43	30	157	157	5446.91	432.942	-39.791	88	-13.5008	99	-35.8735	98	-109.814	
Subject7 mpg21 b sc right	Male	177	75.2	-89	127	4	134	7	102	130	-7	-89	130	13	77	-25	40	130	-7	-10	44	61	157	157	6263.15	481.487	6.61479	100	-29.834	22	3.22808	99	-109.049	
Subject7 mpg21 c ns right	Male	177	75.2	-89	127	12	147	-19	140	111	-7	-89	130	-6	59	-21	15	111	-7	-11	63	49	157	157	3713.15	292.834	-54.4446	70	-6.25534	100	-37.0624	98	-106.764	
Subject8 mpg22 a ace left	Male	177	75.2	-89	127	18	158	-19	106	100	-7	-88	-157	6	54	3	35	100	-7	-23	53	18	157	157	4868.13	385.758	-30.1966	98	-40.1844	58	6.70205	99	-92.0136	
Subject8 mpg22 b sc left	Male	177	75.2	-89	127	19	169	-6	119	135	-7	-88	-157	24	67	-9	20	135	-7	-15	59	33	157	157	4602.61	346.266	-20.7359	99	-40.8822	46	-13.2109	99	-94.8509	
Subject8 mpg22 c ns left	Male	177	75.2	-89	127	19	168	-20	127	125	-7	-88	-157	28	77	-14	23	125	-7	-22	76	29	157	157	2809.84	211.491	-36.5112	96	-32.898	90	-1.27682	100	-98.9062	
Subject8 mpg23 a ace centre	Male	177	75.2	-89	127	21	138	-16	123	109	-7	-88	-157	10	63	-19	56	109	-7	-26	58	28	157	157	4822.98	380.486	-49.2225	80	-13.1648	99	2.8214	99	-110.236	
Subject8 mpg23 b sc centre	Male	177	75.2	-89	70	13	124	-5	127	125	-7	-88	-157	12	66	-8	60	125	-7	-4	81	26	157	157	3680.32	278.309	-54.5501	64	3.1267	100	-10.9073	99	-115.871	
Subject8 mpg23 c ns centre	Male	177	75.2	-89	127	24	115	0	96	150	-7	-88	-157	21	78	3	64	150	-7	-3	86	15	157	157	4103.52	295.229	-39.7512	93	-17.0857	99	4.61858	99	-110.563	
Subject8 mpg24 a ace right	Male	177	75.2	-89	127	38	142	-51	128	110	-7	-88	-157	3	84	-6	21	110	-7	-22	65	55	157	157	3550.49	279.644	-44.8158	93	-6.65631	100	-9.18993	99	-81.7931	2
Subject8 mpg24 b sc right	Male	177	75.2	-89	127	6	119	-7	122	110	-7	-89	130	4	65	-30	46	110	-7	-10	44	61	157	157	5722.3	453.913	-55.146	50	2.90895	100	-46.0503	95	-107.785	
Subject8 mpg24 c ns right	Male	177	75.2	-89	127	30	127	-38	104	111	-7	-89	115	20	82	-21	62	111	-7	-11	73	13	157	157	3944.61	308.317	-46.9513	90	-15.2862	99	-2.6378	100	-94.1628	1
Subject9 mpg25 a ace left	Male	177	75.2	-89	127	20	-163	-26	169	125	-7	-88	-157	27	-3	-3	-9	125	-7	-28	75	51	157	157	527.631	34.5703	-45.9573	89	-21.9594	99	-34.0282	99	-97.0805	
Subject9 mpg25 b sc left	Male	177	75.2	-88	-148	21	-153	-33	-171	140	-7	-88	-157	21	58	-35	-54	140	-7	-15	89	73	157	157	863.025	126.737	-50.9633	85	-14.0374	99	-19.3686	99	-99.981	
Subject9 mpg25 c ns left	Male	177	75.2	-89	127	13	-161	-21	164	145	-7	-88	-157	25	40	4	-22	145	-7	-10	81	50	157	157	1003.68	52.7294	-39.2759	95	-29.1977	95	-31.2026	99	-98.3691	
Subject9 mpg26 a ace centre	Male	177	75.2	-89	127	21	138	-16	123	109	-7	-88	-157	10	63	-19	56	109	-7	-26	58	50	157	157	4821.44	380.366	-49.2225	80	-13.1648	99	2.8214	99	-110.236	
Subject9 mpg26 b sc centre	Male	177	75.2	-89	70	21	179	-18	124	145	-7	-88	-157	9	73	-10	-2	145	-7	-6	76	58	157	157	3092.02	215.639	-28.674	99	-40.7803	34	-24.1689	99	-86.6806	1
Subject9 mpg26 c ns centre	Male	177	75.2	-89	127	25	180	-21	131	140	-7	-88	-157	16	58	-21	-20	140	-7	-13	76	40	157	157	2453.73	168.883	-33.5625	98	-35.9881	79	-19.2628	99	-90.248	
Subject9 mpg27 a ace right	Male	177	75.2	-89	127	15	137	-13	130	90	-7	-88	-157	14	47	-40	20	90	-7	-22	45	55	157	157	5136.91	409.704	-53.4335	65	-6.46471	100	-31.6459	98	-109.741	
Subject9 mpg27 b sc right	Male	177	75.2	-89	127	39	165	-32	113	125	-7	-89	130	-4	97	-8	31	125	-7	-10	44	61	157	157	5553.88	425.575	-33.4954	97	-29.372	79	-32.3322	98	-74.7244	2
Subject9 mpg27 c ns right	Male	177	75.2	-89	127	30	127	-38	104	142	-7	-89	115	20	82	-21	62	142	-7	4	73	30	157	157	4645.57	342.085	-46.9513	91	-15.2861	99	-27.5921	99	-90.091	1

task:	left shoulder (fwd/bkwd	@ left shoulder (adduc./ab	left shoulder (adduc./ab	moment @ torso (flexion):	% capable torso (flexion):	@ torso (lat. bend.):	% capable torso (lat. bend.):	@ torso (axial rot.):	torso (axial rot.):	moment @ right hip:	% capable right hip:	moment @ right knee:	% capable @ right knee:	moment @ right ankle:	% capable right ankle:	moment @ left hip:	% capable @ left hip:	moment @ left knee:	% capable @ left knee:	moment @ left ankle:	% capable left ankle:	L.Erector Spi.	R.Erector Spi.	L.Rectus Abdo.	R.Rectus Abdo.	L.Internal Ob.	R.Internal Ob.	L.External Ob.	R.External Ob.	L.Latis. Dorsi	R.Latis. Dorsi	L4/L5 Disc Compression Force	Anterio-Posterior Shear	Lateral Shear Force	l. upper arm vert. angle:	r. upper arm vert. angle:	l. upper arm horiz. angle:	r. upper arm horiz. angle:	l. humeral rot. angle:	r. humeral rot. angle:	l. elbow included angle:	r. elbow included angle:
Subject 1 mpg1 a Ace Left	99	-105.991	2	-23.4702	99	-299.7	0	-8.83739	100	20.5091	99	-6.35187	0	0	100	211.934	56	594.59	0	-156.695	70	0	39.9733	1041.17	1088.33	0	1197.16	222.556	1368.19	0	668.546	-5029.86	-342.532	-527.931	126	113	59	137	4	31	161	159
Subject1 mpg1 b sc left	97	-93.5617	6	50.5113	99	-238.019	100	61.3194	92	21.4117	99	-3.4961	0	-0.73699	99	208.859	61	589.562	0	-153.786	72	0	85.2565	882.574	922.635	0	1014.9	591.551	1159.88	0	566.762	-4722.22	-738.831	-422.331	122	97	51	81	40	69	154	82
Subject1 mpg1 c ns left	99	-89.0727	4	73.4722	97	-283.452	100	66.4628	86	20.5091	99	-6.35187	0	0	100	276.5	22	658.264	0	-220.716	32	0	0	1051.47	1098.55	0	1208.4	883.94	1380.97	0	463.644	-5383.24	-1046.47	-368.013	121	83	32	113	50	15	123	102
Subject1 mpg2 a ace centre	99	-93.9234	2	-308.209	47	-194.543	93	-69.4162	0	7.34753	100	-6.35187	99		100	-149.197	73	48.1876	96	390.207	0		3129.46	0	1121.37	0	120.04	0	1412.27	87.0944	690.086	-5997.41	-662.597	-613.565	131	115	88	78	40	24	127	138
Subject1 mpg2 b sc centre	99	-61.843	58	-180.374	95	-133.862	98	-32.7431	97	19.8207	99	-5.39887	0	0.822583	99	-151.233	76	231.401	0	205.217	41	360.927	1780.87	0	0	0	510.156	0	803.674	391.314	392.705	-4108.56	-60.7639	-19.6926	66	89	82	123	-15	30	67	127
Subject1 mpg2 c nsc centre	98	-97.3961	0	-188.795	94	-127.523	95	-20.5976	74	20.5091	99	-6.35187	0	0	100	-114.662	87	269.614	0	168.781	63	0	1865.06	0	271.86	0	476.74	0	841.668	405.07	411.27	-4098.84	-141.102	-7.04808	110	100	52	97	91	32	139	146
Subject1 mpg3 a ace right	52	-49.9196	79	-372.188	65	-65.4855	100	-143.072	0	10.3854	100	-6.35187	99	0	100	-356.593	6	-115.97	0	554.364	0	1691.32	2835.95	0	0	0	195.355	0	1279.81	623.959	625.363	-6664.23	-242.955	-47.379	109	115	27	138	27	19	101	146
Subject1 mpg3 b sc right	93	-58.928	51	-342.82	57	-167.498	99	-124.616	0	5.98032	100	-6.35187	99	0	100	-265.13	23	-87.2164	0	525.61	0	0	3243.5	0	302.553	0	169.194	0	1463.74	709.032	715.235	-5786.62	-458.963	-171.081	116	134	25	103	40	49	91	146
Subject1 mpg3 c ns right	97	-56.8641	66	-307.012	61	-86.527	100	-115.009	1	-1.28474	99	-6.35187	99	0	100	-277.71	17	-203.354	0	641.749	0	757.095	2388.28	0	0	0	94.8791	0	1077.79	525.252	526.647	-4731.72	-225.963	-40.4909	72	108	41	121	11	35	75	146
Subject2 mpg4 a ace left	99	-108.851	0	-307.893	47	-171.627	96	-36.8342	60	5.98032	100	-6.35187	99	0	100	-210.26	43	-34.2215	67	472.362	0	0	2825.59	0	370.258	0	416.201	0	1275.14	616.839	623.08	-5348.79	-385.309	-144.586	127	118	76	63	93	69	148	136
Subject2 mpg4 b sc left	84	-73.8033	21	-184.179	93	-153.726	98	-102.478	100	12.405	100	-6.35187	99	0	100	-52.0864	96	215.676	1	222.465	31	0	2402.58	0	862.464	927.934	948.593	0	1084.24	0	419.071	-5970.99	809.221	-335.989	98	108	33	102	66	88	116	123
Subject2 mpg4 c ns left	99	-86.235	5	-348.176	40	-93.0683	100	-42.8459	78	1.20058	100	-6.35187	99	0	100	-294.218	11	-186.417	0	624.558	0	1134.15	2492.3	0	0	0	396.306	0	1124.73	548.188	549.584	-5537.87	-125.233	-143.539	126	96	89	77	32	0	111	110
Subject2 mpg5 a ace centre	99	-98.0059	2	-387.541	26	-22.9397	100	-46.26	12	-1.28474	99	-6.35187	99	0	100	-339.667	3	-267.348	0	705.489	0	1957.27	2481.11	0	0	0	427.196	0	1119.68	545.728	547.118	-6349.96	-48.9826	-116.695	97	124	96	34	14	66	115	153
Subject2 mpg5 b sc centre	99	-97.7802	3	-307.747	48	-66.7482	100	-20.6946	98	-3.46985	99	-9.46369	99	14.7356	99	-260.711	21	-122.236	0	548.753	0	1359.06	2023.66	0	0	0	440.314	0	913.244	444.856	446.245	-5030.42	-90.3459	-74.8535	77	95	86	62	16	37	115	135
Subject2 mpg5 c ns centre	92	-79.0046	16	-246.334	86	40.9716	100	-27.9065	97	-92.1617	91	40.5946	96	135.009	81	-141.355	79	61.3854	88	194.8	47	1674.01	1632.16	0	0	0	100.803	0	192.45	359.79	359.912	-4457.37	89.8314	27.8221	102	117	62	77	57	50	124	159
Subject2 mpg6 a ace right	100	-73.3134	13	-375.33	38	22.365	100	16.7649	99	-120.564	84	-100.771	0	237.212	23	-253.301	26	-205.843	0	501.19	0	2243.57	2187.49	0	0	0	211.131	0	328.547	482.247	482.369	-5509.71	430.407	-86.5973	136	132	91	1	57	39	100	137
Subject2 mpg6 b sc right	91	-98.4328	0	-298.934	65	45.5443	100	-25.6767	95	-86.1171	92	-25.0159	74	157.505	70	-201.421	50	-47.4136	3	346.519	0	1863.41	1816.82	0	0	0	192.844	0	405.221	400.512	400.634	-4847.67	96.1373	7.05339	123	82	90	57	103	32	139	109
Subject2 mpg6 c ns right	96	-69.71	31	-361.41	45	67.892	100	-38.1768	93	-127.064	82	-95.1113	0	243.292	20	-239.31	32	-172.786	0	456.201	0	2184.97	2130.35	0	0	0	79.6185	0	344.905	469.647	469.77	-5288.98	284.557	11.5942	100	131	72	45	34	52	99	120
Subject3 mpg7 a ace left	98	-109.254	0	-391.027	32	-45.0073	100	-117.307	0	1.20058	100	-6.35187	99	0	100	-320.736	7	-212.936	0	651.077	0	891.326	3019.49	0	0	0	209.231	0	1362.64	664.429	665.838	-6010.2	-331.275	-105.411	119	136	89	63	11	66	143	136
Subject3 mpg7 b sc left	76	-100.505	3	-193.659	88	-203.03	94	-106.193	0	5.98032	100	-6.35187	99	0	100	-70.79	94	105.249	72	332.892	1	0	2780.4	0	998.094	1211.74	1091.36	0	1254.75	0	554.727	-6817.25	1002.19	-458.589	103	110	31	120	33	52	153	153
Subject3 mpg7 c ns left	98	-112.632	3	-363.59	38	-62.9849	100	-72.2507	23	1.20058	100	-6.35187	99	0	100	-327.638	5	-219.837	0	657.978	0	1708.59	2429.17	0	0	0	361.132	0	1096.24	534.267	535.664	-5955.49	-101.554	-68.7037	115	120	83	45	-48	66	159	111
Subject3 mpg8 a ace centre	99	-74.1381	22	-392.553	33	8.52687	100	-71.664	0	-1.28474	99	-6.35187	99	0	100	-354.973	3	-282.654	0	720.795	0	1973.68	2500.26	0	0	0	285.628	0	1128.32	549.932	551.34	-6283.35	-54.2361	-104.546	105	134	80	46	10	11	86	158
Subject3 mpg8 b ace centre	56	-91.0913	4	-339.162	65	-5.39666	100	-80.6682	16	-33.6253	98	-13.8498	94	67.2752	97	-283.837	19	-54.6068	0	432.97	0	2175.97	2121.57	0	0	0	379.371	0	845.323	467.712	467.835	-6031.33	26.7307	12.7027	105	92	60	87	82	20	147	121
Subject3 mpg8 c ns centre	99	-100.098	2	-345.464	40	19.647	100	-74.4806	0	-2.55324	99	-7.30069	99	2.78498	99	-307.092	8	-235.092	0	671.397	0	1658.31	2246.09	0	0	0	290.522	0	1013.62	493.896	495.292	-5551.49	-81.4037	-51.763	105	88	102	73	11	7	122	98
Subject3 mpg9 a ace right	99	-99.6807	1	-384.747	35	11.3829	100	-65.0741	24	-37.5714	97	-34.9562	87	72.7308	96	-330.519	5	-265.883	0	659.897	0	2345.01	2286.39	0	0	0	291.993	0	918.59	504.057	504.179	-6211.12	70.3914	-49.6524	115	140	89	45	33	66	127	106
Subject3 mpg9 b sc right	74	-94.9483	4	-396.838	36	89.5901	100	-74.2965	10	-100.35	89	-87.0261	1	188.79	51	-309.324	10	-257.206	0	587.036	0	2493.19	2430.86	0	0	0	66.7156	0	612.351	535.915	536.037	-6149.69	177.132	16.112	121	116	92	80	38	37	143	127
Subject3 mpg9 c ns right	99	-77.1717	17	-361.392	27	56.8351	100	-38.5314	94	-129.64	80	-141.128	0	287.902	6	-238.493	29	-262.63	0	547.45	0	2250.59	2194.32	0	0	0	63.7559	0	362.118	483.755	483.877	-5413.76	254.969	10.489	95	139	91	73	28	75	93	140
Subject4 mpg10 a ace left	67	-99.6326	4	-394.945	40	-69.5707	100	-131.575	0	1.20058	100	-6.35187	99	0	100	-363.406	2	-255.606	0	693.747	0	1457.18	2901.61	0	0	0	116.449	0	1309.45	638.445	639.844	-6285.63	-283.792	-73.4348	121	143	62	95	-2	78	143	136
Subject4 mpg10 b sc left	89	-89.1489	11	-251.051	85	-184.149	99	-105.147	7	13.5492	100	-6.35187	99	0	100	-212.289	48	71.809	86	366.332	0	0	2657.43	0	148.109	0	351.97	0	1199.25	579.754	585.999	-4978.46	-296.987	-63.4992	96	121	34	119	-6	59	115	130
Subject4 mpg10 c ns left	82	-64.9634	56	-229.646	90	-113.959	100	-148.728	0	13.5492	100	-6.35187	99	0	100	-154.544	75	129.554	37	308.587	3	0	2564.86	0	640.768	0	139.571	0	1157.48	559.384	565.586	-5267.29	-376.914	-53.0893	72	114	38	118	-5	60	94	118
Subject4 mpg11 a ace centre	97	-71.6227	31	-376.729	37	12.2264	100	-62.6741	25	-38.978	97	-35.8758	86	76.4472	96	-320.65	7	-256.501	0	647.718	0	2287.09	2229.91	0	0	0	293.728	0	901.129	491.603	491.725	-6069.42	74.0722	-49.5613	95	132	73	63	4	24	86	158
Subject4 mpg11 b sc centre	100	-100.967	3	-117.955	98	-156.655	38	6.30629	100	17.5515	99	-6.35187	94	0	100	-17.6753	98	324.787	0	113.589	89	0	1759.9	159.317	632.016	221.353	695.217	0	794.534	0	0	-4220.79	168.518	1.34406	76	80	59	100	14	15	124	133
Subject4 mpg11 c ns centre	99	-89.7161	6	-138.76	96	-216.488	8	-20.193	100	16.0017	100	-6.35187	98	0	100	15.7074	100	334.821	0	103.32	91	0	2557	736.539	918.157	373.775	1009.97	0	1154.25	0	0	-6351.03	257.966	-42.0516	94	105	48	109	27	5	113	153
Subject4 mpg12 a ace right	8	-77.0857	10	-390.859	26	-41.9227	100	-78.3445	45	-26.0698	98	-26.071	97	43.8339	99	-350.084	3	-350.105	0	764.131	0	2430.11	2369.35	0	0	0	284.957	0	1061.3	522.352	522.474	-6481.04	-25.2486	-53.7579	145	125	45	77	91	46	138	108
Subject4 mpg12 b sc right	86	-74.0677	28	-341.251	72	6.35178	100	-113.958	0	16.0017	99	-6.35187	98	0	100	-317.455	13	0	100	437.449	0	1896.94	2461.12	0	0	0	415.152	0	1110.66	541.317	542.708	-6526.01	-120.11	-12.5977	100	125	73	111	23	44	108	154
Subject4 mpg12 c ns right	98	-111.661	0	-352.705	34	66.5779	100	-39.4445	79	-105.559	87	-88.0894	1	214.225	35	-246.696	27	-198.723	0	504.182	0	2206.58	2151.41	0	0	0	138.385	0	454.988	474.293	474.415	-5463.95	135.763	10.8331	113	118	108	60	30	63	154	135
Subject5 mpg13 a ace left	95	-102.925	9	-391.255	32	-59.8854	100	-135.25	0	-4.82468	99	-6.35187	99	0	100	-365.527	2	-343.746	0	781.887	0	1664.2	2817.1	0	0	0	51.9395	0	1271.31	619.809	621.207	-6280.95	-298.433	-48.9796	143	124	81	112	-98	62	143	149
Subject5 mpg13 b sc left	99	-85.1958	7	-24.2489	99	-256.072	0	36.2598	99	16.0017	100	-6.35187	98	0	100	79.6683	99	398.782	0	39.3591	99	0	1433.98	862.477	901.637	0	991.801	117.874	1133.49	0	553.863	-5565.66	-247.016	-448.64	97	90	15	113	43	37	107	109
Subject5 mpg13 c ns left	99	-83.1457	10	-38.4841	99	-269.737	0	40.8742	98	13.5492	100	-6.35187	99	0	100	38.5606	99	322.659	0	115.482	88	0	1914.54	857.044	895.954	0	985.549	0	1126.34	0	483.636	-5834.69	-145.993	-411.038	104	108	23	132	37	56	110	152
Subject5 mpg14 a ace centre	91	-67.2826	42	-399.024	30	-42.7933	100	-73.0685	73	-47.2931	97	-47.2955	79	88.6252	94	-347.069	3	-347.088	0	737.547	0	2456.68	2395.26	0	0	0	195.465	0	943.554	528.065	528.187	-6376.23	60.7795	-55.6835	102	143	51	85	-3	25	86	158
Subject5 mpg14 b sc centre	99	-95.3155	1	-178.036	92	-178.719	37	4.86835	100	16.3257	99	-6.35187	97	0	100	-88.8433	91	236.241	0	202.135	43	0	2031.37	0	727.208	0	495.972	0	916.723	354.688	447.945	-4701.14	-213.148	-110.625	114	97	56	76	67	59	133	117
Subject5 mpg14 c ns centre	78	-62.5311	52	-292.904	73	-48.8195	100	-146.468	100	8.23836	100	-6.35187	99	0	100	-210.373	47	-2.09698	99	440.238	0	0	2694.16	0	298.39	0	106.947	0	1215.83	587.817	594.098	-4931.88	-386.512	-44.4956	89	123	47	103	43	89	108	164
Subject5 mpg15 a ace right	99	-52.6684	72	-374.497	36	-4.71843	100	-47.4707	92	-76.8791	93	-76.8833	20	158.003	70	-294.213	12	-294.23	0	644.9	0	2251.64	2195.34	0	0	0	168.944	0	700.968	483.98	484.102	-5724.31	198.52	-52.9212	72	132	89	75	4	25	56	139
Subject5 mpg15 b sc right	4	-61.8547	50	-352.16	61	88.0319	100	-157.967	0	3.62843	100	-6.35187	99	0	100	-347.393	5	-206.651	0	644.598	0	1374.47	2668.52	0	0	55.9709	0	0	1204.25	588.443	588.318	-5793.2	-203.991	-12.6746	116	112	73	67	93	47	148	116
Subject5 mpg15 c ns right	99	-112.971	0	-349.528	47	68.4502	100	-21.335	97	-102.44	89	-65.4308	3	192.539	49	-244.048	30	-143.951	0	448.438	0	2122.43	2069.37	0	0	0	177.281	0	416.698	456.202	456.324	-5285.49	229.105	-22.5345	119	80	109	46	41	19	154	94
Subject6 mpg16 a ace left	44	-90.4085	4	-375.31	35	-116.451	100	-120.585	0	-1.28474	99	-6.35187	99	0	100	-327.149	5	-254.83	0	692.971	0	943.136	3022.72	0	0	0	154.609	0	1364.1	665.153	666.549	-6005.13	-377.455	-93.3859	127	122	42	106	62	49	143	149
Subject6 mpg16 b sc left	99	-106.895	1	-37.3377	99	-267.106	0	21.0864	99	18.9193	99	-6.35187	69	0	100	160.222	85	520.99	0	-82.849	95	0	427.105	932.096	974.371	0	1071.81	150.616	1224.92	0	598.543	-4883.81	-282.784	-462.935	108	85	46	100	20	32	145	121
Subject6 mpg16 c ns left	99	-112.38	6	-266.724	84	-78.494	99	-45.6469	81	4.93307	100	0.551566	99	17.1493	99	-225.559	44	114.32	40	299.768	4	1451.8	1932.64	0	0	0	555.842	0	872.164	424.782	426.172	-5384.06	-31.3007	-9.7297	114	74	87	78	-87	48	158	97
Subject6 mpg17 a ace centre	99	-112.238	1	-249.875	82	-240.525	30	-65.7473	0	18.9193	99	-6.35187	69	0	100	-59.8022	96	300.966	0	137.175	80	0	3152.5	0	1131.67	801.428	1244.72	0	1422.67	0	453.371	-7407.28	601.338	-423.398	114	111	83	87	-4	37	148	143
Subject6 mpg17 b sc centre	99	-91.5133	3	-192.661	92	-172.163	43	3.82355	100	18.9193	99	-6.35187	69	0	100	-97.1403	90	264.69	0	173.687	60	0	2059.98	0	620.994	0	622.672	0	929.634	448.048	454.254	-4817.14	-140.562	-38.2995	86	98	56	100	60	92	117	173
Subject6 mpg17 c ns centre	98	-103.116	1	-245.762	86	-102.071	99	-25.3683	99	0.672754	100	4.07382	99	22.588	99	-208.503	50	123.593	30	281.534	7	1338.61	1827.5	0	0	0	551.625	0	824.717	401.597	402.987	-5092.5	-38.3378	-11.5701	119	94	60	101	66	36	156	131
Subject6 mpg18 a ace right	54	-82.8718	9	-421.676	21	3.73123	100	-98.3387	0	-6.35187	99	-6.35187	99	0	100	-390.683	0	-390.705	0	828.846	0	2299.89	2714.34	0	0	0	173.264	0	1224.93	597.152	598.548	-6838.4	-158.106	-76.9801	130	141	63	60	50	64	131	139
Subject6 mpg18 b sc right	99	-58.5651	51	-319.523	49	-70.3241	100	-37.3478	85	3.62843	100	-6.35187	99	0	100	-276.451	16	-135.71	0	573.656	0	1237.44	2168.58	0	0	0	382.872	0	978.643	476.807	478.201	-5107.49	-100.089	-93.0692	79	114	69	86	53	-1	76	159
Subject6 mpg18 c ns right	99	-115.864	0	-428.335	32	41.4434	100	-35.3351	97	-117.09	86	-83.4715	0	201.046	43	-309.207	11	-205.72	0	519.74	0	2634.72	2568.85	0	0	0	161.194	0	496.089	566.343	566.465	-6486.8	297.089	-24.4206	134	151	105	71	24	89	160	161
Subject7 mpg19 a ace left	60	-103.549	0	-373.891	35	-118.024	100	-107.763	1	-1.28474	99	-6.35187	99	0	100	-322.76	6	-250.441	0	688.582	0	948.777	2979.87	0	0	0	191.006	0	1344.76	655.697	657.1	-5972.22	-347.09	-107.495	135	118	50	78	60	48	161	117
Subject7 mpg19 b sc left	99	-116.946	1	-320.697	69	-128.418	99	-108.313	0	14.2819	100	-6.35187	99	0	100	-219.736	45	74.8231	84	363.318	0	0	2949.37	0	184.785	0	465.372	0	1331	644.147	650.374	-5589.8	-289.22	-108.712	134	102	83	70	-21	38	174	81
Subject7 mpg19 c ns left	99	-91.3977	6	-267.066	84	-59.2612	100	-59.887	0	18.9193	99	-6.35187	69	0	100	-194.447	58	166.321	4	271.82	10	554.584	2164.23	0	0	0	538.515	0	976.68	475.853	477.242	-4870.1	-105.347	-33.2327	83	89	96	76	13	19	104	100
Subject7 mpg20 a ace centre	99	-113.445	0	-401.726	52	-57.822	100	-91.4143	0	14.2819	99	-6.35187	99	0	100	-358.016	5	-63.457	0	501.598	0	1964.14	2844.95	0	0	0	571.677	0	1283.88	625.95	627.349	-7231.83	-84.4527	-82.4394	119	122	93	86	11	24	150	140
Subject7 mpg20 b sc centre	99	-102.146	4	-241.212	87	-127.357	99	-40.1739	68	18.9193	99	-6.35187	69	0	100	-185.889	61	174.795	2	263.325	12	328.371	2150.89	0	0	0	530.082	0	970.659	472.909	474.3	-4593.26	-144.346	-27.6359	71	76	81	92	-9	26	124	116
Subject7 mpg20 c ns centre	99	-111.412	1	-260.161	83	-25.423	100	-29.0295	82	-15.2084	98	11.5602	99	42.0075	99	-200.118	54	108.611	46	269.61	10	1647.5	1688.96	0	0	0	511.223	0	762.198	371.043	372.438	-5156.22	-25.8746	5.48831	86	81	96	83	22	19	147	131
Subject7 mpg21 a ace right	48	-66.2331	37	-411.934	36	-22.4939	100	-131.743	0	1.20058	100	-6.35187	99	0	100	-365.46	2	-257.66	0	695.801	0	1341.01	3035.16	0	0	0	67.3059	0	1369.71	667.892	669.292	-6363.98	-328.22	-101.205	125	142	50	94	47	58	116	160
Subject7 mpg21 b sc right	86	-90.5761	7	-393.937	59	138.987	99	-94.2714	100	-12.2969	99	-14.4349	93	33.9793	99	-386.7	3	-136.948	0	548.998	0	2744.75	2676.13	0	0	0	290.673	0	990.388	590	590.122	-7367.23	27.9128	-21.5787	112	154	107	36	20	94	128	148
Subject7 mpg21 c ns right	94	-91.9334	5	-334.64	50	-45.8746	100	-107.522	0	4.10546	100	-6.35187	99	0	100	-273.768	18	-126.205	0	564.151	0	590.786	2595.4	0	0	0	199.459	0	1171.26	570.912	572.321	-5001.94	-299.473	-45.8635	91	102	73	86	54	27	135	148
Subject8 mpg22 a ace left	56	-103.059	1	-378.109	34	-116.358	100	-110.651	0	-1.28474	99	-6.35187	99	0	100	-325.364	6	-253.045	0	691.186	0	926.784	3021.04	0	0	0	174.303	0	1363.34	664.781	666.179	-6006	-361.25	-111.904	137	119	50	77	60	47	161	117
Subject8 mpg22 b sc left	83	-86.5849	9	-344.71	67	-78.1806	100	-109.274	0	14.2819	99	-6.35187	99	0	100	-296.626	17	-2.06709	99	440.208	0	1141.98	2712.18	0	0	0	455.498	0	1223.96	596.661	598.072	-6133.62	-171.411	-56.0506	109	126	55	82	29	65	123	125
Subject8 mpg22 c ns left	100	-90.0888	3	-274.59	71	-169.94	98	-50.0072	66	10.3854	100	-6.35187	99	0	100	-210.059	45	28.8693	98	409.272	0	0	2568.13	0	118.663	0	421.946	0	1158.95	560.063	566.306	-4772.04	-283.848	-99.292	104	98	56	95	46	42	113	124
Subject8 mpg23 a ace centre	99	-112.956	0	-393.85	32	-88.9048	100	-82.7409	0	3.14836	100	-6.35186	99	0	100	-333.166	5	-197.559	0	635.699	0	1227.87	2921.59	0	0	0	368.151	0	1318.46	642.846	644.249	-6307.71	-229.667	-124.248	117	120	94	85	16	19	150	140
Subject8 mpg23 b sc centre	99	-115.965	0	-282.923	64	-75.1721	99	-21.3987	99	-14.1616	98	-7.51449	99	41.8378	99	-233.301	33	-17.8936	91	415.339	0	1486.09	1860.35	0	0	0	453.724	0	839.542	408.841	410.231	-5018.74	-104.103	-18.9657	95	98	87	101	15	-7	159	162
Subject8 mpg23 c ns centre	100	-112.664	0	-261.461	81	-49.3087	100	0	100	-51.2966	96	22.1113	98	85.1576	95	-185.554	60	76.535	78	247.985	18	1754.19	1710.33	0	0	0	404.19	0	501.13	377.029	377.151	-5012.49	61.4839	-14.6132	102	98	79	81	36	34	157	150
Subject8 mpg24 a ace right	98	-83.7216	5	-333.024	48	-28.7631	100	-77.5943	0	3.62843	100	-6.35187	99	0	100	-261.622	22	-119.16	0	557.301	0	626.452	2466.76	0	0	0	303.905	0	1113.2	542.557	543.952	-4923.93	-179.791	-100.168	116	77	78	66	68	11	116	90
Subject8 mpg24 b sc right	89	-98.2828	5	-397.537	44	131.463	99	-104.755	100	-4.30444	99	-11.3656	99	13.6188	99	-398.027	1	-260.205	0	689.546	0	2583.86	2519.27	0	0	0	221.46	0	1106.26	555.409	555.532	-6850.81	-32.0878	-28.5085	110	135	115	64	8	5	141	167
Subject8 mpg24 c ns right	100	-107.402	1	-302.713	53	-81.8773	100	-20.7444	99	-34.8903	97	-24.1101	93	77.5268	96	-246.766	27	-120.596	0	498.753	0	1820.87	1825.51	0	0	0	425.99	0	823.821	401.152	402.55	-5162.34	-26.0394	-54.0955	94	76	77	91	27	16	135	109
Subject9 mpg25 a ace left	78	-102.934	4	-217.547	87	-224.707	92	-133.156	0	10.3854	100	-6.35187	99	0	100	-64.5213	95	174.407	12	263.733	12	0	3242.67	0	1164.04	1038.9	1280.32	0	1463.36	0	93.4292	-7311.51	892.385	-184.84	112	96	43	111	-7	42	149	127
Subject9 mpg25 b sc left	99	-36.9132	92	-126.236	97	-181.27	66	-35.7663	100	16.0017	99	-6.35187	98	0	100	8.86967	100	329.381	0	108.999	90	0	2250.63	544.45	808.178	442.806	888.996	0	1015.99	0	0	-5671.75	370.482	-44.8538	62	71	28	113	72	23	61	123
Subject9 mpg25 c ns left	96	-81.9983	11	-170.981	95	-185.942	90	-63.4941	0	17.5515	99	-6.35187	94	0	100	-73.3371	94	267.902	0	170.239	63	0	2253.15	0	808.824	421.851	556.965	0	1016.81	0	496.622	-5195.95	150.322	-383.722	98	83	27	110	52	55	117	132
Subject9 mpg26 a ace centre	99	-112.956	0	-402.126	29	-7.80464	100	-91.2414	0	3.14836	100	-6.35186	99	0	100	-332.928	5	-197.32	0	635.461	0	1291.79	2901.48	0	0	0	355.507	0	1309.39	638.404	639.815	-6340.07	-204.595	-117.556	117	120	116	63	16	19	150	140
Subject9 mpg26 b sc centre	99	-74.2857	19	-255.497	85	-61.4898	100	-59.8157	0	17.5515	99	-6.35187	94	0	100	-193.289	58	147.854	14	290.267	5	527.215	2072.83	0	0	0	445.89	0	935.431	455.694	457.086	-4601.17	-141.532	-15.0052	86	92	60	64	64	60	103	113
Subject9 mpg26 c ns centre	99	-71.0634	27	-229.045	88	-145.25	99	-67.257	1	16.0017	99	-6.35187	98	0	100	-159.529	71	159.585	10	278.556	8	0	2285.63	0	268.383	0	405.416	0	1031.47	497.827	504.012	-4620.51	-227.114	-46.6407	76	92	29	88	54	49	95	114
Subject9 mpg27 a ace right	91	-88.4717	12	-388.646	30	47.011	100	-149.791	100	-6.35187	99	-6.35187	99	0	100	-332.319	5	-332.34	0	770.481	0	995.63	3103.75	0	0	86.6225	0	0	1400.67	684.417	684.293	-6134.56	-333.366	-89.7675	97	132	98	68	0	26	120	151
Subject9 mpg27 b sc right	67	-64.737	39	-356.754	67	116.637	99	-98.906	100	-10.4037	99	-13.1398	97	31.2621	99	-346.225	7	-122.79	0	536.262	0	2430.74	2369.98	0	0	0	269.635	0	1016.78	522.489	522.611	-6655.46	-8.75293	-20.6682	119	114	88	46	56	46	114	94
Subject9 mpg27 c ns right	99	-105.645	1	-298.305	75	23.6313	100	-32.2706	96	-87.0176	92	5.07526	99	134.641	81	-194.988	57	16.9775	99	274.88	9	1949.2	1900.47	0	0	0	197.225	0	381.915	418.957	419.079	-5169.36	96.7518	14.7521	88	74	94	70	16	29	135	109

APPENDIX NO. 23:

L4 L5 DISK COMPRESSION FORCES"

Table A23.1 L4 L5 Disk Compression Forces[49] (Newton)				
Position	**Subject**	**ACE**	**SC**	**NS**
left	subject1	-5029.86	-4722.22	-5383.24
	subject2	-5348.79	-5970.99	-5537.87
	subject3	-6010.2	-6817.25	-5955.49
	subject4	-6285.63	-4978.46	-5267.29
	subject5	-6280.95	-5565.66	-5834.69
	subject6	-6005.13	-4883.81	-5384.06
	subject7	-5972.22	-5589.8	-4870.1
	subject8	-6006	-6133.62	-4772.04
	subject9	-7311.51	-5671.75	-5195.95
right	subject1	-6664.23	-5786.62	-4731.72
	subject2	-5509.71	-4847.67	-5288.98
	subject3	-6211.12	-6149.69	-5413.76
	subject4	-6481.04	-6526.01	-5463.95
	subject5	-5724.31	-5793.2	-5285.49
	subject6	-6838.4	-5107.49	-6486.8
	subject7	-6363.98	-7367.23	-5001.94
	subject8	-4923.93	-6850.81	-5162.34
	subject9	-6134.56	-6655.46	-5169.36
centre	subject1	-5997.41	-4108.56	-4098.84
	subject2	-6349.96	-5030.42	-4457.37
	subject3	-6283.35	-6031.33	-5551.49
	subject4	-6069.42	-4220.79	-6351.03
	subject5	-6376.23	-4701.14	-4931.88
	subject6	-7407.28	-4817.14	-5092.5
	subject7	-7231.83	-4593.26	-5156.22
	subject8	-6307.71	-5018.74	-5012.49
	subject9	-6340.07	-4601.17	-4620.51
	Mean	-6202.40	-5501.49	-5239.90
	SD	585.09	851.30	513.70

[49] Negative values represent direction in relation to a datum used by the Michigan Program to aggregate muscle forces on the disk (see *Michigan (1998)*)

APPENDIX NO. 24:

L5 S1 DISK COMPRESSION FORCES

Table A24.1
L5 S1` Disk Compression Forces
(Newton)

Position	Subject	ACE	SC	NS
left	subject1	3327.34	3023.48	3777.07
	subject2	2430.86	616.286	4037.15
	subject3	4743.62	532.992	4641.4
	subject4	5259.4	3211.82	2699.14
	subject5	5288.12	1771.29	1335.48
	subject6	4864.7	2676.31	3876.55
	subject7	4804.3	3443.66	3210.04
	subject8	4868.13	4602.61	2809.84
	subject9	527.631	863.025	1003.68
right	subject1	5568.2	3977.75	3753.39
	subject2	5051.8	4326.2	5034.4
	subject3	5188.08	5622.27	5182.38
	subject4	5374.65	5047.97	4996.96
	subject5	5105.54	4727.31	4829.62
	subject6	5801.36	3756.85	6027.57
	subject7	5446.91	6263.15	3713.15
	subject8	3550.49	5722.3	3944.61
	subject9	5136.91	5553.88	4645.57
centre	subject1	1221.11	2695.81	1907.92
	subject2	4863.39	3620.83	4194.11
	subject3	5115.8	4771.65	4353.81
	subject4	5053.11	320.105	996.785
	subject5	5532.42	1181.47	2990.53
	subject6	351.839	1404.05	3640.23
	subject7	5569.4	2947.06	3783.94
	subject8	4822.98	3680.32	4103.52
	subject9	4821.44	3092.02	2453.73
	Mean	4432.95	3313.05	3627.50
	SD	1503.99	1690.54	1254.94

APPENDIX NO. 25:

DIRECT MEASUREMENT OF BAGGAGE HANDLER REACH AND TRUNK ROTATION

MEASUREMENT OF REACH (cm)

Position	Subject	ACE	SC	NS
left	subject1	100.62	78.26	78.26
	subject2	121.86	93.35	75.46
	subject3	103.41	82.73	83.29
	subject4	105.65	72.11	88.88
	subject5	115.71	114.59	103.41
	subject6	91.67	77.70	82.73
	subject7	116.83	86.64	74.90
	subject8	108.44	84.96	65.96
	subject9	107.32	73.78	80.49
right	subject1	111.80	106.21	89.44
	subject2	100.62	103.41	88.32
	subject3	126.89	84.96	107.88
	subject4	114.03	109.00	83.29
	subject5	124.09	70.99	86.08
	subject6	117.39	102.29	90.55
	subject7	121.86	109.56	80.49
	subject8	107.88	97.82	103.41
	subject9	101.73	70.43	73.78
centre	subject1	109.00	117.39	100.62
	subject2	125.77	95.03	97.82
	subject3	109.56	83.85	103.97
	subject4	117.94	96.70	110.68
	subject5	121.86	114.03	109.56
	subject6	123.53	114.03	124.09
	subject7	124.65	115.71	101.73
	subject8	102.85	117.39	105.09
	subject9	123.53	95.03	83.29
Mean		113.21	95.11	91.61
SD		9.40	15.50	13.78

MEASUREMENT OF TRUNK ROTATION (degrees)

Position	Subject	ACE	SC	NS
left	subject1	29	22	53
	subject2	27	33	33
	subject3	31	32	28
	subject4	32	73	70
	subject5	9	16	27
	subject6	67	52	20
	subject7	29	38	50
	subject8	28	26	15
	subject9	50	22	25
right	subject1	90	60	86
	subject2	41	46	26
	subject3	30	34	49
	subject4	18	15	42
	subject5	18	32	31
	subject6	18	72	50
	subject7	23	70	62
	subject8	52	53	29
	subject9	51	30	40
centre	subject1	13	10	20
	subject2	20	28	28
	subject3	31	27	16
	subject4	17	46	19
	subject5	17	20	13
	subject6	30	31	24
	subject7	20	19	34
	subject8	33	32	13
	subject9	37	29	5
	Mean	31.89	35.85	33.63
	SD	17.37	17.23	18.66

APPENDIX NO. 26:

CPE RESPONSE DATA: "HIGHEST" RISK OF BACK INJURY

Table A26.1
Highest Risk of Back Injury

Position	Subject	No. of times judged "Highest"		
		ACE	SC	NS
left	subject1	7	0	2
	subject2	9	0	0
	subject3	4	2	3
	subject4	8	0	1
	subject5	8	0	1
	subject6	9	0	0
	subject7	7	0	2
	subject8	3	2	4
	subject9	5	3	1
	subject10	9	0	0
	subject11	8	0	1
	subject12	9	0	0
	subject13	9	0	0
	subject14	3	1	5
	subject15	8	1	0
	subject16	8	1	0
	subject17	5	1	3
	subject18	9	0	0
	subject19	9	0	0
	subject20	9	0	0
right	subject1	9	0	0
	subject2	9	0	0
	subject3	3	4	2
	subject4	7	0	2
	subject5	7	0	2
	subject6	9	0	0
	subject7	9	0	0
	subject8	5	0	4
	subject9	6	2	1
	subject10	9	0	0
	subject11	9	0	0
	subject12	9	0	0
	subject13	7	2	0
	subject14	3	5	1
	subject15	9	0	0
	subject16	8	1	0
	subject17	7	1	1
	subject18	9	0	0
	subject19	9	0	0
	subject20	9	0	0

Table A26.1 (Cont.) Highest Risk of Back Injury				
Position	Subject	No. of times judged "Highest"		
		ACE	SC	NS
centre	subject1	9	0	0
	subject2	9	0	0
	subject3	3	4	2
	subject4	7	2	0
	subject5	6	1	2
	subject6	9	0	0
	subject7	9	0	0
	subject8	6	1	2
	subject9	6	3	0
	subject10	9	0	0
	subject11	9	0	0
	subject12	9	0	0
	subject13	7	2	0
	subject14	6	2	1
	subject15	9	0	0
	subject16	9	0	0
	subject17	9	0	0
	subject18	9	0	0
	subject19	9	0	0
	subject20	9	0	0
	Mean	7.6	0.68	0.72
	SD	1.91	1.18	1.18

APPENDIX NO. 27:

CPE RESPONSE DATA: “LOWEST” RISK OF BACK INJURY

Table A27.1
Lowest Risk of Back Injury

Position	Subject	No. of times judged “Lowest”		
		ACE	SC	NS
left	subject1	1	5	3
	subject2	0	6	3
	subject3	1	3	5
	subject4	1	5	3
	subject5	0	6	3
	subject6	0	4	5
	subject7	2	3	4
	subject8	4	3	2
	subject9	0	2	7
	subject10	0	1	8
	subject11	1	3	5
	subject12	0	2	7
	subject13	0	4	5
	subject14	6	1	2
	subject15	1	3	5
	subject16	0	5	4
	subject17	1	5	3
	subject18	0	4	5
	subject19	0	1	8
	subject20	0	2	7
right	subject1	0	3	6
	subject2	0	4	5
	subject3	2	1	6
	subject4	1	3	5
	subject5	0	7	2
	subject6	0	7	2
	subject7	0	4	5
	subject8	1	4	4
	subject9	0	2	7
	subject10	0	0	9
	subject11	0	3	6
	subject12	0	3	6
	subject13	1	5	3
	subject14	1	1	7
	subject15	0	1	8
	subject16	0	3	6
	subject17	0	4	5
	subject18	0	1	8
	subject19	0	5	4
	subject20	0	2	7

Table A27.1 (Cont.) Lowest Risk of Back Injury				
Position	**Subject**	**No. of times judged "Lowest"**		
		ACE	**SC**	**NS**
centre	subject1	0	3	6
	subject2	0	4	5
	subject3	3	1	5
	subject4	1	4	4
	subject5	2	2	5
	subject6	0	6	3
	subject7	0	3	6
	subject8	0	5	4
	subject9	0	1	8
	subject10	0	0	9
	subject11	0	4	5
	subject12	0	4	5
	subject13	0	3	6
	subject14	2	1	6
	subject15	0	2	7
	subject16	0	4	5
	subject17	0	3	6
	subject18	0	3	6
	subject19	0	2	7
	subject20	0	3	6
	Mean	0.53	3.15	5.32
	SD	1.09	1.65	1.76

APPENDIX NO. 28:

CPE DATA: RATINGS DERIVED FROM ERGONOMISTS OPINIONS CONCERNING POSTURES WITH HIGHEST AND LOWEST RISK OF BACK INJURY

For the purposes of conducting analysis of variance and mixed model analysis across all the CPE opinion data sets, the opinion data for both the “Highest” and “Lowest” Risk of Back Injury sets were merged into a single rating. For each of the 20 ergonomists and for each set of three postures (see Appendix 10), each time a posture was judged “Highest” risk of an injury the corresponding aircraft configuration scored three (3) points and each time a posture was judged “Lowest” risk of an injury the corresponding aircraft configuration scored one (1) point. In each set, the aircraft configuration that was judged neither “highest” nor ”lowest” risk of an injury, by each ergonomist, scored two points.

The resultant ratings are detailed in Table A28.1.

Table A28.1
Ergonomist Opinion Data: Ratings

Subject	1.1	1.2	1.3	2.1	2.2	2.3	3.1	3.2	3.3
1	23	27	27	13	15	15	17	12	12
2	27	27	27	12	14	14	15	13	13
3	21	18	19	17	21	21	16	15	14
4	25	24	24	13	16	15	16	14	15
5	26	22	25	12	17	11	16	15	18
6	27	27	27	14	12	11	13	15	16
7	24	27	27	15	15	14	16	12	13
8	17	24	22	13	14	14	20	16	18
9	23	24	24	19	20	18	12	10	12
10	27	27	27	17	18	18	10	9	9
11	25	27	27	15	14	15	14	13	12
12	27	27	27	16	14	15	11	13	12
13	27	25	24	14	17	15	13	12	15
14	15	22	20	18	19	22	21	13	12
15	25	27	27	16	16	17	13	11	10
16	26	27	26	14	14	16	14	13	12
17	22	27	25	14	15	15	18	12	14
18	27	27	27	14	15	17	13	12	10
19	27	27	27	17	16	13	10	11	14
20	27	27	27	16	15	16	11	12	11

Legend:

Configuration	Bag Position	Examples
ACE=1	Left =1	1.3 means *ACE* configuration, Right bag position
Sliding Carpet=2	Centre =2	2.2 means *Sliding Carpet* configuration, Centre bag position
“No System”=3	Right =3	3.1 means “No System” configuration, Left bag position

APPENDIX NO. 29:

STATISTICAL CORROBORATION

As described in the Chapter 2 methods for Phase 4 of this study, some statistics authors warned against ignoring the intrinsic errors and assumptions of the various statistical tests. They recommended that if the consequences of a study were significant, additional appropriate tests should be carried out to corroborate the returns of the parametric tests and then investigate and explain any variations between the various test outcomes.

For example, the statistical corrections applied to account for a spurious outcome of a statistical test due to chance, the Bonferroni correction, reported to be the most powerful methods of its type, and which was applied in this study, was reported in the literature to only reduce the probability of that chance outcome occurring once in 200 occasions ($5x10^{-3}$).

Accordingly, the additional tests detailed in Table 2.4, were conducted where appropriate, to corroborate the principal test outcomes in this study. Since, if spurious results were reported from the study they could have a significant and lasting negative effect on the risk of injury to baggage handlers and the viability of the manufacturers and airline companies involved could be effected resulting in major financial losses to the industry if those defective study outcomes resulted in ineffective or harmful corrective actions.

The following describes the application of those additional statistical tests conducted.

Biomechanical data

The calculations of significance of the differences between the results for both L4L5 and L5S1 data between the three mock-up configurations, *ACE, Sliding Carpet* and *"No System"*, are described below.

The four tests for normality (see table 2.4) indicated, at the 0.05 confidence level, that normal distributions could be assumed for all three L4L5 data sets: *Ace, Sliding Carpet* and “No System”.

However, the normality tests of the L5 S1 data sets produced a mixed result. Four tests indicated that the L5 S1 disc compression data related to the *ACE* configuration did not conform to a normal distribution, with confidence set at the 0.05 (95%) level. All four tests indicated that the *Sliding Carpet* related L5 S1 disc compression data could be considered normally distributed and three of the four tests indicated similarly for the L5 S1 disc compression data from the “No System” configuration trials. The Lilliefors test suggested that the “No System” related data may not have conformed to a normal distribution, at the 0.05 confidence level.

Consequently, to ensure these deviations from normality in the L5 S1 data were taken into account, only non-parametric tests of significance of difference between the *Ace, Sliding Carpet* and “No System” data sets were selected for these data.

The experimental design in this study attempted to control for all the potentially confounding variables which could cause changes in posture and hence in disc compression. Therefore the three data sets were assumed to be only dependent on baggage compartment configuration. Statistical tests for two or more independent samples were selected, as follows:

L4L5 Tests:

Parametric: Bartlett’s Test and the Levene Test

Non-parametric: Friedman’s Test and the Multiple Comparisons Test

L5S1 Tests:

Non-parametric: Friedman’s Test and the Multiple Comparisons Test

In addition, to provide a high level of confidence in the efficacy of the test outcomes, three separate Mann-Whitney tests were conducted to measure any differences in disc compression forces between *Ace* and *Sliding Carpet* , *Ace* and “No System” and *Sliding Carpet* and “No System”

This was carried out for both the L4L5 and L5S1 disc compression data sets (see Appendices Nos. 23 and 24 respectively).

The results of these tests for the L4L5 data sets are detailed in Table A29.1

:

Table A29.1
Results of Tests: L4L5 Disc Compression Data
Differences between *Ace, Sliding Carpet* and “No System”

Tests with measures across all three data sets *Ace, Sliding Carpet* and “No System”			
Test	**Result**		
Bartletts	SIGNIFICANT difference across the three data sets		
Levene	SIGNIFICANT difference across the three data sets		
Friedman	SIGNIFICANT difference across the three data sets		
Tests between pairs of data: ACE v SC, ACE v NS and SC v NS			
Test	**Ace v SC**	**Ace v NS**	**SC v NS**
Multiple Comparisons	SIGNIFICANT	SIGNIFICANT	Not Significant
Mann-Whitney	SIGNIFICANT	SIGNIFICANT	Not Significant

In relation to the L4L5 disc compression data, all of the tests which compared the data across all three data sets found significant differences between the *Ace, Sliding Carpet* and “No System” data sets, at a significance level of 0.05. However, the tests which compared data between pairs of samples, the Multiple Comparisons test and the Mann-Whitney test, found that there were significant differences between the L4L5 disc compression data of ACE and *Sliding Carpet* and between *ACE* and “No System”. However, these tests indicated there was not a significant difference between the L4L5 disc compression data of *Sliding Carpet* and “No System”.

Since the mean L4L5 disc compression force for *ACE* was 6202.40N and for *Sliding Carpet and* “No System” were 5501.40N and 5239.90 respectively, it can be assumed from these results that postures adopted by baggage handlers stacking baggage into *ACE* generated statistically significantly higher L4L5 disc compression forces and therefore the postures represented a higher risk of L4L5 injury than when stacking baggage into either *Sliding Carpet* or into a baggage compartment with no system fitted.

A similar result was obtained by analysis of the L5S1 disc compression data, as Table A29.2 shows.

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Table A29.2 Results of Tests: L5S1 Disc Compression Data Differences between *ACE, Sliding Carpet* and "No System"			
Tests with measures across all three data sets *ACE, Sliding Carpet* and "No System"			
Test	**Result**		
Friedman	SIGNIFICANT difference across the three data sets		
Tests between pairs of data: ACE v SC, ACE v NS and SC v NS			
Test	**ACE v SC**	**ACE v NS**	**SC v NS**
Multiple Comparisons	SIGNIFICANT	SIGNIFICANT	Not Significant
Mann-Whitney	SIGNIFICANT	SIGNIFICANT	Not Significant

The mean L5S1 disc compression force for *ACE* was 4432.95N and for *Sliding Carpet* and "No System" were 3313.05N and 3627.50 respectively. Accordingly, it can be assumed from these results that postures adopted by baggage handlers stacking baggage into *ACE* generate statistically significantly higher L5S1 disc compression forces and therefore the postures represented a higher risk of L4L5 injury than when stacking baggage into either *Sliding Carpet* or into a baggage compartment with no system fitted.

These two measures of compression forces on the discs of the lower back suggest there was a significantly higher risk of low back injury for baggage handlers stacking baggage into an *ACE* system compared to stacking baggage into either *Sliding Carpet* or into a baggage compartment with no system fitted.

Method 2: Direct Measurement of Baggage Stacking Postures

Figure A29.1 shows that for the baggage handlers' reach data, *ACE* resulted in baggage handlers reaching significantly further than either *Sliding Carpet* or *"No-System"* populations.

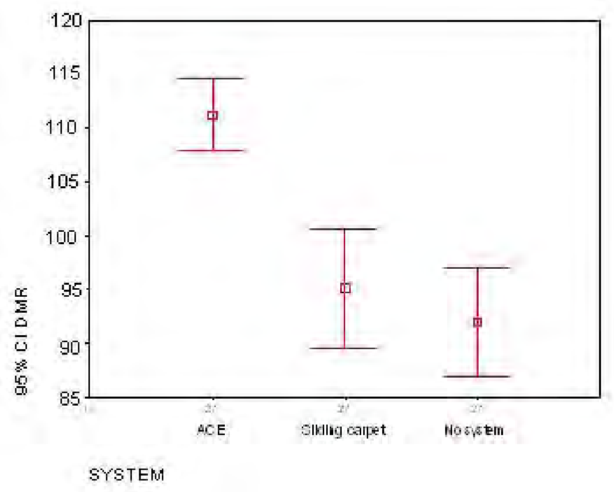

Figure A29.1
Comparison of Baggage Handlers Reach
(centimetres)

All four normality tests (table 2.4) indicated, at the 0.05 (95%) confidence level, that normal distributions could be assumed for all three Reach data sets: *Ace, Sliding Carpet* and "No System". However, the normality tests of the baggage handler trunk rotation data sets produced a mixed result. At the 0.05 confidence level, all four tests indicated that the ACE related trunk rotation data was most probably not normally distributed and three of the four tests indicated the *Sliding Carpet* related trunk rotation data was also not normally distributed. However, the Jarque –Bera test for the *Sliding Carpet* related trunk rotation data failed at the 0.05 confidence level.

All four normality tests indicated the "No System" related trunk rotation data set was normally distributed.

Consequently, to ensure these deviations from normality in the data were taken into account, both parametric and non-parametric tests of significance of difference between the *Ace, Sliding Carpet* and "No System" data sets were selected for these data.

Figure A29.2 shows that there was little difference in baggage handlers trunk rotations between the *ACE* , *Sliding Carpet* and *"No-System"* populations with significant population overlap.

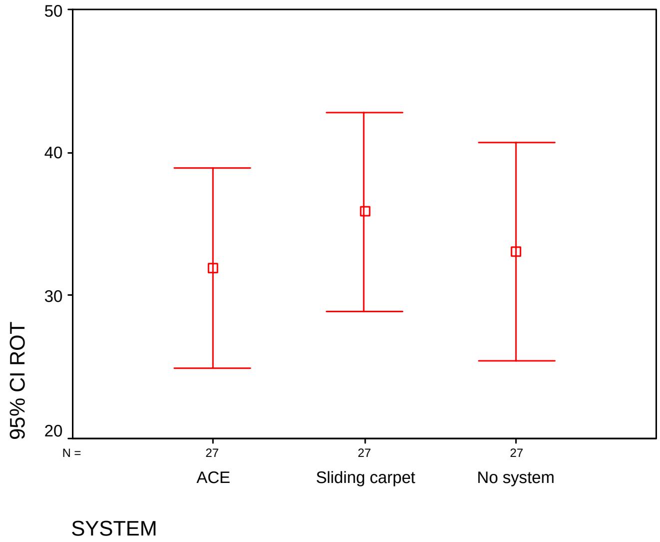

Figure A29.2
Comparison of Baggage Handlers Trunk Rotation
(Degrees of rotation)

As stated previously, the experimental design in this study was intended to control for all the potentially confounding variables, including those which could have caused changes in posture and resultant changes in both reach and trunk rotation. Therefore the three data sets were assumed to be only dependent on baggage compartment configuration. Statistical tests for two or more independent samples were selected, as follows:

Parametric: Bartlett's Test and the Levene Test

Non-parametric: Friedman's Test and the Multiple Comparisons Test

In addition, to provide a high level of confidence in the efficacy of the test outcomes, three separate Mann-Whitney tests for both the Reach data sets and the Trunk Rotation data sets were conducted to measure any differences between *Ace* and *Sliding Carpet*, between A*ce* and “No System” and between *Sliding Carpet* and “No System”.

The results of these tests for the Reach data sets are detailed in Table A29.3

Table A29.3 Results of Tests: Direct Measure Reach Data Differences between *Ace, Sliding Carpet* and “No System”			
Tests with measures across all three data sets *Ace, Sliding Carpet* and “No System”			
Test	**Result**		
Bartletts	SIGNIFICANT difference across the three data sets		
Levene	SIGNIFICANT difference across the three data sets		
Friedman	SIGNIFICANT difference across the three data sets		
Tests between pairs of data: ACE v SC, ACE v NS and SC v NS			
Test	**Ace v SC**	**Ace v NS**	**SC v NS**
Multiple Comparisons	SIGNIFICANT	SIGNIFICANT	Not Significant
Mann-Whitney	SIGNIFICANT	SIGNIFICANT	Not Significant
Wilcoxon signed ranks	SIGNIFICANT	SIGNIFICANT	Not Significant
Sign test	SIGNIFICANT	SIGNIFICANT	Not Significant

In relation to the Direct Measure Reach data, all of the tests which compared the data across all three data sets found significant differences between the *Ace, Sliding Carpet* and “No System” data sets, at a significance level of 0.05. However, the four tests which compared data between pairs of samples, the Multiple Comparisons test, the Mann-Whitney test, the Wilcoxon signed ranks test and the Sign test, all confirmed that there were significant differences, at the 0.05 significance level, between *Ace* and *Sliding Carpet,* and between *Ace* and “No System”.

However, all four of these tests indicated there was not a significant difference in the Direct Measure Reach data between *Sliding Carpet* and “No System”.

Since the mean score for ACE was 113.21 cm and the means for *Sliding Carpet and* “No System” were 95.11cm and 91.61cm, it can be assumed from these results that postures adopted by baggage handlers stacking baggage into ACE generated statistically significantly greater reach distances than when stacking baggage into either *Sliding Carpet* or into a baggage compartment with no system fitted.

Given that reaching while lifting has previously been identified as a major back injury risk factor and the higher the moment of the load, that is the greater the distance of the load from the spine, the higher the risk (see for example McGill (2002): p96), this comparison of reach distances and associated postures suggests there is a significantly higher risk of back injury for baggage handlers stacking baggage into an *ACE* system compared to stacking baggage into either *Sliding Carpet* or into a baggage compartment with no system fitted.

However, all of the tests of the trunk rotation measures found the three mock-up configurations did not produce significant differences in trunk rotation, as Table A29.4 shows.

:

Table A29.4
Results of Tests: Direct Measure Trunk Rotation Data
Differences between *Ace, Sliding Carpet* and "No System"

Tests with measures across all three data sets *Ace, Sliding Carpet* and "No System"			
Test	**Result**		
Friedman	Difference across the three data sets: Not Significant		
Levene	Difference across the three data sets: Not Significant		
Friedman	Difference across the three data sets: Not Significant		
Tests between pairs of data: ACE v SC, ACE v NS and SC v NS			
Test	**Ace v SC**	**Ace v NS**	**SC v NS**
Multiple Comparisons	Not Significant	Not Significant	Not Significant
Mann-Whitney	Not Significant	Not Significant	Not Significant
Wilcoxon signed ranks	Not Significant	Not Significant	Not Significant
Sign test	Not Significant	Not Significant	Not Significant

Further discussion of this unexpected result concerning the trunk rotation data can be found in Chapter 4.

Ergonomists Opinion Data

The normality tests (see Table 2.4) using the “Highest Risk of Back Injury” data across the three mock-up configurations *Ace*, *Sliding Carpet* and “No System”, all indicated, at the 0.05 confidence level, that non-normal distributions could be assumed for all three “Highest Risk of Back Injury” data sets: *Ace, Sliding Carpet* and “No System”. However, the normality tests of the “Lowest Risk of Back Injury” data sets produced a mixed result. All four tests indicated that the ACE related “Lowest Risk of Back Injury” data was most probably not normally distributed, at the 0.05 confidence level and three of the four tests indicated both the *Sliding Carpet* and “No System” related data was also not normally distributed. However, the Jarque –Bera tests for the *Sliding Carpet* and “No System” related “Lowest Risk of Back Injury” data failed at the 0.05 confidence level.

Consequently, to ensure these deviations from normality in the data were taken into account, non-parametric tests of significance of difference between the *Ace, Sliding Carpet* and “No System” data sets were selected for these data.

Once more, due to the experimental design to control for all the potentially confounding dependent variables, statistical tests for two or more independent samples were selected, as follows:

Non-parametric: The Kruskal Wallis Test, Friedman’s Test and the Multiple Comparisons Test

To provide a high level of confidence in the test outcomes, the range of non parametric tests were conducted to confirm any differences between pairs of the data sets, *Ace* and *Sliding Carpet* , between A*ce* and “No System” and between *Sliding Carpet* and “No System”.

The tests conducted were the Mann-Whitney test , the Wilcoxon signed ranks test and the Sign Test

These were conducted for both the “Highest Risk of Back Injury” data sets and the “Lowest Risk of Back Injury” data sets.

The results of these tests for the “Highest Risk of Back Injury” data sets are detailed in Table A29.5.

In relation to the “Highest Risk of Back Injury” data, all of the tests which compared across all three data sets found there were significant differences across the *Ace, Sliding Carpet* and “No System” data sets, at a significance level of 0.05.

However, the tests which compared data between pairs of samples, the Multiple Comparisons test, the Mann-Whitney test, the Wilcoxon signed ranks test and the Sign test, all found that there were significant differences, at the 0.05 significance level, between the ACE and *Sliding Carpet* data sets and between ACE and “No System” data sets. Hoewever, all these tests indicated there was not a significant difference between the *Sliding Carpet* and “No System” data sets for the “Highest Risk of Back Injury” category.

Table A29.5
Results of Tests: CPE “Highest Risk of Back Injury” Data
Differences between *Ace, Sliding Carpet* and “No System”

Tests with measures across all three data sets *Ace, Sliding Carpet* and “No System”			
Test	**Result**		
Kruskal Wallis	SIGNIFICANT difference across the three data sets		
Friedman	SIGNIFICANT difference across the three data sets		
Tests between pairs of data: ACE v SC, ACE v NS and SC v NS			
Test	**Ace v SC**	**Ace v NS**	**SC v NS**
Multiple Comparisons	SIGNIFICANT	SIGNIFICANT	Not Significant
Mann-Whitney	SIGNIFICANT	SIGNIFICANT	Not Significant
Wilcoxon signed ranks	SIGNIFICANT	SIGNIFICANT	Not Significant
Sign test	SIGNIFICANT	SIGNIFICANT	Not Significant

Since the mean score for ACE was 7.6 and the means for *Sliding Carpet and* “No System” were 0.68 and 0.72 respectively, it can be assumed that postures adopted by baggage handlers represented a higher risk of back injury when stacking baggage into ACE than when stacking baggage into *Sliding Carpet* or into a baggage compartment with no system fitted, based on the statistically significant consensus of opinion amongst the ergonomists who participated in this study.

Analysis of the "Lowest Risk of Back Injury" data sets found statistically significant differences, at the 0.05 significance level, across all three mock-up configurations: *ACE, Sliding Carpet* and "No System", as Table A29.6 shows.

Table A.29.6 Results of Tests: CPE "Lowest Risk of Back Injury" Data Differences between *ACE, Sliding Carpet* and "No System"			
Tests with measures across all three data sets *Ace, Sliding Carpet* and "No System"			
Test	**Result**		
Kruskal Wallis	SIGNIFICANT difference across the three data sets		
Friedman	SIGNIFICANT difference across the three data sets		
Tests between pairs of data: ACE v SC, ACE v NS and SC v NS			
Test	**Ace v SC**	**Ace v NS**	**SC v NS**
Multiple Comparisons	SIGNIFICANT	SIGNIFICANT	SIGNIFICANT
Mann-Whitney	SIGNIFICANT	SIGNIFICANT	SIGNIFICANT
Wilcoxon signed ranks	SIGNIFICANT	SIGNIFICANT	SIGNIFICANT
Sign test	SIGNIFICANT	SIGNIFICANT	SIGNIFICANT

At the 0.05 significance level, both tests which compared across all three data sets found significant differences across the data sets, and the four tests which compared data between pairs of samples, all found that there were significant differences between *Ace* and *Sliding Carpet* , between *Ace* and "No System", and also between *Sliding Carpet* and "No System

Since the mean score for "No System" was 5.32, for *Sliding Carpet* was 3.15 and for *ACE* was 0.53, it can be assumed that postures adopted by baggage handlers represented the lowest risk of back injury when stacking baggage into the mock-up configured to represent a baggage compartment with no system, but that postures adopted when stacking into the *Sliding Carpet* configuration were a lower risk of back injury than when stacking into *ACE*, based on the statistically significant consensus of opinion amongst the ergonomists who participated in this study.

Comparison of CPE Opinion Data Sorted for Top Row Bag Positions: Left, Centre and Right

While the study results of difference between *ACE* and *Sliding Carpet* and between *ACE* and "No System" may have been forecast, due to the higher step presented to the baggage handlers by ACE and the additional depth of the *ACE* bin section when positioned closest to the baggage handlers, the result of "No System" having lower risk of back injury than "Sliding Carpet" warranted further investigation.

There were, in effect, only two differences in the layout and configuration of the baggage handlers' workplace between *Sliding Carpet* and "No System" that could have influenced their lifting posture. These were the 19cm step presented to the baggage handler by the end of the *Sliding Carpet* system, and the inward opening aircraft baggage compartment door protruded into the workspace when loading *Sliding Carpet*, sometimes restricting head room of the baggage handlers (see for example Figures 2.1 & 2.2), an obstruction clearly not present when stacking baggage in the interior of a baggage compartment not fitted with a system.

These configuration differences were fundamental in the experimental design for this project via the design of the mock-up and the mock-up configuration for each trial sequence (see Table 2.3).

The data capture in this study did not permit the effect of the 1.9cm step to be isolated in a comparison of results between the *Sliding Carpet* and "No System" mock-up configurations. However, the CPE opinion results data was re-sorted to provide a comparison between the top left bag position, top centre bag position and top right bag position, where the effect of the aircraft door could perhaps be isolated. As Figure 2.4 shows, the aircraft door does not create a head room restriction when stacking baggage away from door, but could do so when stacking in the top centre position and when stacking toward the door (Figure 2.1). Accordingly, since the mock-up in this study was designed to simulate compartment No 3 of a B737 aircraft, the door would present a potential headroom restriction for top centre and top right bag positions but not for the top left position.

Sorting the data in this way also ensured the effect of the 1.9cm step in the *Sliding Carpet* configuration was controlled across the data sets since it was common across the data sets being compared.

The CPE opinion data for “Lowest Risk of Back Injury”, for the two configurations *Sliding Carpet* and “No System” was sorted for the three top row bag positions Left, Centre and Right.

The population means and standard deviations for the three data sets *Ace*, *Sliding Carpet* and “No System”, sorted for the top row Left, Centre and Right bag positions are shown in Tables A29.7, A29.8 and A29.9 respectively.

Table A29.7
Top Row Left Data Set

Measure	*Sliding Carpet*	“No System”
Mean Score	3.40	4.70
SD	1.56	1.85

For each set n=20; twenty CPE subjects x 1 bag position

Table A29.8
Top Row Centre Data Set
(Rating Score)

Measure	*Sliding Carpet*	“No System”
Mean Score	2.90	5.70
SD	1.45	1.35

For each set n=20; twenty subjects x 1 bag positions

Table A29.9
Top Row Right Data Set
(Rating Score)

Measure	*Sliding Carpet*	“No System”
Mean Score	3.15	5.32
SD	1.65	1.76

For each set n=20; twenty subjects x 1 bag positions

All of the normality tests conducted using the “Left”, “Centre” and Right bag position data sets across the three mock-up configurations *Ace*, *Sliding Carpet* and “No System” suggested the data sets were normally distributed, except for the Lilliefors Test for the Centre bag position “No System” data, which at the 0.05 significance level, rejected the null hypothesis that the sample followed a normal distribution.

Accordingly, to ensure the deviations from normality in the data were taken into account, both parametric and non-parametric tests of significance of difference were selected for these data.

The results of these tests for the “Left”, “Centre” and Right bag position data sets, across the two mock-up configurations *Sliding Carpet* and “No System”, are detailed in Table A29.10, A29.11 and A29.12 respectively.

Table A29.10
Results of Tests for Difference: CPE Opinion – “Left” Bag Position: *Sliding Carpet* and “No System”

Test	Result
Kruskal Wallis	SIGNIFICANT DIFFERENCE
Friedman Test	Not Significant difference
Multiple Comparisons Test	Not Significant difference
Mann-Whitney	SIGNIFICANT DIFFERENCE
Students t-test	SIGNIFICANT DIFFERENCE
Z-test	SIGNIFICANT DIFFERENCE
Mann-Whitney Test	SIGNIFICANT DIFFERENCE
Kolmogorov-Smirnov Test	Not Significant difference
Wilcoxon signed ranks	SIGNIFICANT
Sign test	SIGNIFICANT

Table A29.11
Results of Tests for Difference: CPE Opinion – “Centre” Bag Position: *Sliding Carpet* and “No System”

Test	Result
Kruskal Wallis	SIGNIFICANT DIFFERENCE
Friedman Test	SIGNIFICANT DIFFERENCE
Multiple Comparisons Test	SIGNIFICANT DIFFERENCE
Mann-Whitney	SIGNIFICANT DIFFERENCE
Students t-test	SIGNIFICANT DIFFERENCE
Z-test	SIGNIFICANT DIFFERENCE
Mann-Whitney Test	SIGNIFICANT DIFFERENCE
Kolmogorov-Smirnov Test	SIGNIFICANT DIFFERENCE
Wilcoxon signed ranks	SIGNIFICANT DIFFERENCE
Sign test	SIGNIFICANT DIFFERENCE

Table A29.12
Results of Tests for Difference: CPE Opinion – “Right” Bag Position: *Sliding Carpet* and “No System”

Test	Result
Kruskal Wallis	SIGNIFICANT DIFFERENCE
Friedman Test	SIGNIFICANT DIFFERENCE
Multiple Comparisons Test	SIGNIFICANT DIFFERENCE
Mann-Whitney	SIGNIFICANT DIFFERENCE
Students t-test	SIGNIFICANT DIFFERENCE
Z-test	SIGNIFICANT DIFFERENCE
Mann-Whitney Test	SIGNIFICANT DIFFERENCE
Kolmogorov-Smirnov Test	SIGNIFICANT DIFFERENCE
Wilcoxon signed ranks	SIGNIFICANT DIFFERENCE
Sign test	SIGNIFICANT DIFFERENCE

As Tables A29.11 and A29.12 show, all the tests indicated, at the 0.05 confidence level, there was a significant difference between *Sliding Carpet* and “No System” for the “Centre” and “Right” bag position data sets. However, three of the ten tests for the “Left” bag position data sets (see Table A29.10) failed to reject the null hypothesis that there were no differences between the *Sliding Carpet* and “No System” data.

Accordingly, based on the statistically significant consensus of opinion of ergonomists in this study, the case is stronger that the postures adopted by baggage handlers represented a higher risk of back injury when the aircraft door has an influence on their work space, such as when stacking baggage to the right and centre bag positions.

APPENDIX NO. 30:

MANUAL HANDLING RISK ASSESSMENT OF PROTOTYPE TELAIR LONGREACH LOADER

PROTOTYPE TELAIR LONGREACH LOADER MANUAL HANDLING RISK ASSESSMENT

DATE:7/5/03	FACILITATOR: Geoff Dell	Page 1 of 5
AREA/LOCATION: **Sydney Airport**	**EQUIPMENT TYPE: LONGREACH LOADER**	
RISK ASSESSMENT TEAM : Airline: John Cree, Mark Bernhardt, Mark Weismantel, Greg Palmer, Graeme Clough, Telair: Patrik Olsson, Kenneth Nilsson, David Burton,		

HAZ NO.	CATEGORY	HAZARD	CURRENT CONTROLS	STRENGTHS & WEAKNESSES	RISK SCORE
ASSESSMENT OF AIRCRAFT LOADING RISK WITHOUT LONGREACH LOADER					
1	ERGONOMICS	LIFTING AND STACKING BAGGAGE INTO THE LOCKER OF NARROW BODY AIRCRAFT	1. Manual handling lifting training 2. 32Kg baggage weight limit 3. 50Kg cargo weight limit 4. Physical fitness training 5. Team lift procedure for over 32kg	1. Not all ports conduct training 1a. Training not relevant to work inside aircraft lockers 2. 32Kg limit not applied by all airlines 4. Not all airports have fitness training & training is informal at many of the ports that do 5. There is not always a second person available to perform team lift	C4E
ASSESSMENT OF ERGONOMICS ISSUES WITH USE OF LONGREACH LOADER					
2	ERGONOMICS	MANUAL HANDLING INCORRECT POSITIONING OF LONGREACH LOADER IN NARROW BODY A/C INCREASES RISK AS LONGREACH LOADER MAY BECOME A BARRIER THAT THE OPERATOR HAS TO WORK AROUND	Manufacturers manuals & guidance	Inexperience with Longreach Loader	D 4 H
3	ERGONOMICS	SMALL ITEMS MUST BE LIFTED BECAUSE THEY MAY NOT BE SUPPORTED BY LONGREACH LOADER BALL TRAY AND OTHER BAGS/FREIGHT (SMALL ITEMS MAY OTHERWISE FALL DOWN GAP BETWEEN BALL TRAY AND STACK)	Manufacturers manuals & guidance	Inexperience with Longreach Loader	D 4 H

CATEGORIES:	**Biological** ie Hep A, HIV	**Ergonomic** ie Manual handling, OOS
Physical ie Noise, temp, light, radiation, etc	**Psychological** ie Stress, violence	**Slips/trips/falls** ie Falls from height / same level
Chemical ie Hazard /dangerous goods, spills	**Fire / Explosion** ie Gas, petrol, combustible	**Confined space** ie Vessels, pits, tanks
Mechanical ie Plant (crush, entanglement, hit, cut)	**Electrical** ie Power point, cables	Some categories may require detailed assessments

PROTOTYPE TELAIR LONGREACH LOADER MANUAL HANDLING RISK ASSESSMENT

DATE:7/5/03	FACILITATOR: Geoff Dell	Page 2 of 5
AREA/LOCATION: **Sydney Airport**	**EQUIPMENT TYPE: LONGREACH LOADER**	
RISK ASSESSMENT TEAM : Airline: John Cree, Mark Bernhardt, Mark Weismantel, Greg Palmer, Graeme Clough, Telair: Patrik Olsson, Kenneth Nilsson, David Burton,		

HAZ NO.	CATEGORY	HAZARD	CURRENT CONTROLS	STRENGTHS & WEAKNESSES	RISK SCORE
4	ERGONOMICS	LATERAL LOAD ON OPERATOR PUSHING & PULLING WITH ONE HAND/ARM WHICH MAY SOMETIMES BE THE PERSONS NON-DOMINANT HAND/ARM	Manufacturers manuals & guidance	Inexperience with Longreach Loader Pre-existing injury may limit operators ability	C 3 H
5	ERGONOMICS	PULLING THE LONGREACH LOADER INTO HOLD SOMETIMES REQUIRES EFFORT	Motor torque setting adjustment	Inadequate for Wide body heights	C3H
6	ERGONOMICS	SOME LARGE AND/OR HEAVY ITEMS (EG DOG CAGE) WILL NOT FIT WITH LONGREACH LOADER IN LOCKER	Awareness of operators		C4H
7	ERGONOMICS	OPERATOR WEARING SAFETY GLOVES MAY HAVE DIFFICULTY OPERATING CONTROLS AND SWITCHES.	Nil	May tend to reduce the operators ability to position the unit, reducing its effectiveness and increasing the manual handling load on the loader	C4H
8	ERGONOMICS	BALL TRAY INCLINES UPWARD WHEN LONGREACH LOADER FULLY RAISED CAUSING PROBLEM WHEN PLACED IN BULK HOLD	Nil	Increases M/H load due to instability of load on sloping ball tray	C2M
9	ERGONOMICS	CAN KNOCK THE CONTROL BAR WITH A BAG AND MOTORS THE LONGREACH LOADER AWAY FROM THE OPERATOR	Nil	Bagge handlers could be faced with a heavy bag coming of the loader if the loader moved unexpectedly. This could place a baggage handler in a high manual handling risk circumstance if the baggage handler attempted to prevent the bag from falling	D4H

CATEGORIES:	**Biological** ie Hep A, HIV	**Ergonomic** ie Manual handling, OOS
Physical ie Noise, temp, light, radiation, etc	**Psychological** ie Stress, violence	**Slips/trips/falls** ie Falls from height / same level
Chemical ie Hazard /dangerous goods, spills	**Fire / Explosion** ie Gas, petrol, combustible	**Confined space** ie Vessels, pits, tanks
Mechanical ie Plant (crush, entanglement, hit, cut)	**Electrical** ie Power point, cables	Some categories may require detailed assessments

PROTOTYPE TELAIR LONGREACH LOADER MANUAL HANDLING RISK ASSESSMENT

DATE:7/5/03	FACILITATOR: Geoff Dell	Page 3 of 5
AREA/LOCATION: **Sydney Airport**	**EQUIPMENT TYPE: LONGREACH LOADER**	
RISK ASSESSMENT TEAM : Airline: John Cree, Mark Bernhardt, Mark Weismantel, Greg Palmer, Graeme Clough, Telair: Patrik Olsson, Kenneth Nilsson, David Burton,		

HAZ NO.	CATEGORY	HAZARD	CURRENT CONTROLS	STRENGTHS & WEAKNESSES	RISK SCORE
10	ERGONOMICS	LONGREACH LOADER TILTING TO STOWED (VERTICAL) POSITION	Manual handling activity at present	Approx 30 kg lift required	D3M

COMMENTS:
This report addresses the ergonomic / manual handling issues related to use of the Telair Longreach Loader only.
A separate report of other operational issues has been prepared.

CATEGORIES:	**Biological** ie Hep A, HIV	**Ergonomic** ie Manual handling, OOS
Physical ie Noise, temp, light, radiation, etc	**Psychological** ie Stress, violence	**Slips/trips/falls** ie Falls from height / same level
Chemical ie Hazard /dangerous goods, spills	**Fire / Explosion** ie Gas, petrol, combustible	**Confined space** ie Vessels, pits, tanks
Mechanical ie Plant (crush, entanglement, hit, cut)	**Electrical** ie Power point, cables	Some categories may require detailed assessments

PROTOTYPE TELAIR LONGREACH LOADER MANUAL HANDLING RISK ASSESSMENT

DATE:7/5/03	FACILITATOR: Geoff Dell	Page 4 of 5
AREA/LOCATION: **Sydney Airport**	**EQUIPMENT TYPE: LONGREACH LOADER**	
RISK ASSESSMENT TEAM : Airline: John Cree, Mark Bernhardt, Mark Weismantel, Greg Palmer, Graeme Clough, Telair: Patrik Olsson, Kenneth Nilsson, David Burton,		

CONTROL ACTION PLAN

Haz No.	INTERVENTION STRATEGIES	STRENGTHS & WEAKNESSES	RISK SCORE
ASSESSMENT OF AIRCRAFT LOADING RISK WITH LONGREACH LOADER			
1	Use the Longreach Loader to position the baggage and cargo to the height & position required in the cargo hold.	Use of the Longreach loader eliminates the need to lift baggage and cargo. Therefore, it results in a significant reduction in the manual handling risk. High risk lifting and twisting actions observed in loading without a Longreach Loader are entirely eliminated by use of the loader. However, risk does not reduce to zero, since baggage handlers are still required to push/pull baggage and cargo on/off the Longreach Loader To gain maximum benefit from the Longreach Loader in loading narrow body aircraft, the unit needed to be used in conjunction with a sliding carpet installation in the aircraft. The Longreach loader was also very effective in reducing the lifting tasks associated with the loading of commuter aircraft such as the Dash 8 and the bulk holds of wide body aircraft	E4M
ASSESSMENT OF ERGONOMICS ISSUES WITH USE OF LONGREACH LOADER			
2	Cover this issue in training of operators Include in Standard Operating Procedures	Baggage handlers observed using the Longreach Loader quickly adapted to loading and unloading with the unit with very limited briefing. Baggage handlers' observation of the units operation by an experienced Telair operator and simple to use controls made transitioning to the unit a very quick. All baggage handlers observed using the unit for the first time took less than two loading sequences to become proficient in using the loader. All handlers immediately gained the reduced lifting benefit immediately, even during the initial use period when developing proficiency	E 4 M
3	Position small and light items centrally on belt and with one corner pointing in the direction of belt motion Cover this issue in training of operators Include in Standard Operating Procedures	As per 2 above Positioning these items in this manner significantly reduced the frequency of these items failing to transit the loader efficiently	E 4 M
4	Cover this issue in training of operators Include in Standard Operating Procedures	As per 2 above	D 3 M
5	Torque to adjusted torque settings	The adjustments to motor torque by Telair during the risk assessment/trials period reduced	E 3 M

CATEGORIES:	**Biological** ie Hep A, HIV	**Ergonomic** ie Manual handling, OOS
Physical ie Noise, temp, light, radiation, etc	**Psychological** ie Stress, violence	**Slips/trips/falls** ie Falls from height / same level
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PROTOTYPE TELAIR LONGREACH LOADER MANUAL HANDLING RISK ASSESSMENT		
DATE:7/5/03	FACILITATOR: Geoff Dell	Page 5 of 5
AREA/LOCATION: **Sydney Airport**	**EQUIPMENT TYPE: LONGREACH LOADER**	
RISK ASSESSMENT TEAM : Airline: John Cree, Mark Bernhardt, Mark Weismantel, Greg Palmer, Graeme Clough, Telair: Patrik Olsson, Kenneth Nilsson, David Burton,		

Haz No.	INTERVENTION STRATEGIES	STRENGTHS & WEAKNESSES	RISK SCORE
	Telair to review torque settings to minimise force required to pull LONGREACH LOADER into wide body a/c	the manual handling load to negligible since the unit drove itself in the direction commanded by the operator once the torque settings were correctly set.	
6	Cover this issue in training of operators Include in Standard Operating Procedures	The Longreach loader occupies some of the doorsill to top of door aperture and this reduces the maximum height of items that can be loaded with the unit. Development of procedures to stow these items in the doorway at floor level will reduce the impact of this limitation. Training of personnel to plan the loading sequence to accommodate these unusual large or bulky items will be necessary to ensure the manual handling benefits of the loader are not degraded.	E 4 M
7	Evaluate effectiveness/types of gloves Design controls to take into account operation when wearing industrial gloves	Controls designed to be operated with normal industrial gloves will significantly reduce the likelihood of inadvertent or incorrect control operation	E4M
8	Adjust ball tray angle Install a manual adjustment of Ball tray angle	The ability to adjust the ball tray angle will allow operators to position the ball tray at the optimum angle regardless of the elevation of the belt loader or the angle of the Longreach Loader belt in relation to the aircraft compartment floor. This will enhance the useability of the unit in both narrow body aircraft compartments and wide body aircraft bulk holds.	D2L
9	Redesign control bar to reduce the risk of inadvertent control bar activation	Control bar design that prevents activation when bumped would reduce the likelihood of baggage and cargo knocking the bar and inadvertently moving the Longreach Loader	E4M
10	Telair to review with a view to power assist the unit's stowage function	Power assisted stowage to the vertical position would eliminate the manual handling risk associated with manually stowing the unit	E3M

CATEGORIES:	**Biological** ie Hep A, HIV	**Ergonomic** ie Manual handling, OOS
Physical ie Noise, temp, light, radiation, etc	**Psychological** ie Stress, violence	**Slips/trips/falls** ie Falls from height / same level
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Mechanical ie Plant (crush, entanglement, hit, cut)	**Electrical** ie Power point, cables	Some categories may require detailed assessments

APPENDIX NO. 31:
BAGGAGE HANDLER SUBJECT HEART RATES

The nine baggage handler subjects stacked baggage into the mock-up in three trial sequences, once each for *Ace*, *Sliding Carpet* and "*No System*", in the order detailed in Table A31.1.

Table A31.1
Order of Trials

Subject 1	Ace, Sliding Carpet, No System	Subject 6	No System, Sliding Carpet, Ace
Subject 2	No System, Sliding Carpet, Ace	Subject 7	Ace, No System, Sliding Carpet
Subject 3	Ace, Sliding Carpet, No System	Subject 8	Sliding Carpet, No System, Ace
Subject 4	Sliding, Carpet Ace, No System	Subject 9	Ace, Sliding Carpet, No System
Subject 5	Ace, Sliding Carpet, No System		

Figures A31.1 to A31.9 graph the heart rates recorded for the nine baggage handler subjects. They clearly show that the loading sequences in this study were too short a duration for heart rates to plateau and provide a differential measure of subject workload.

Figure A31.1

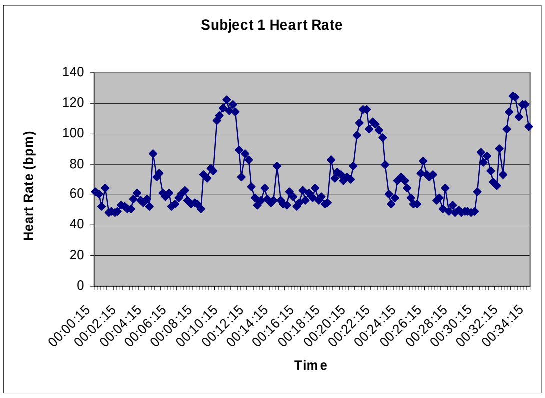


Figure A31.2

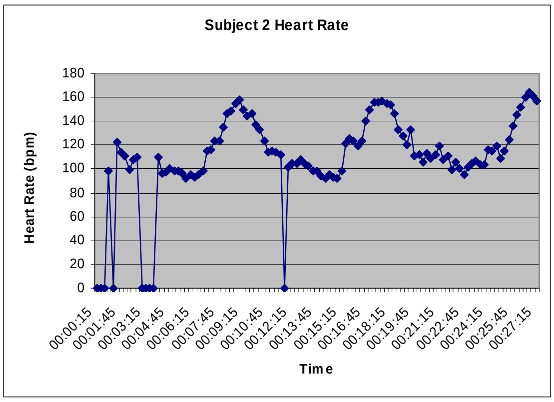


Figure A31.3

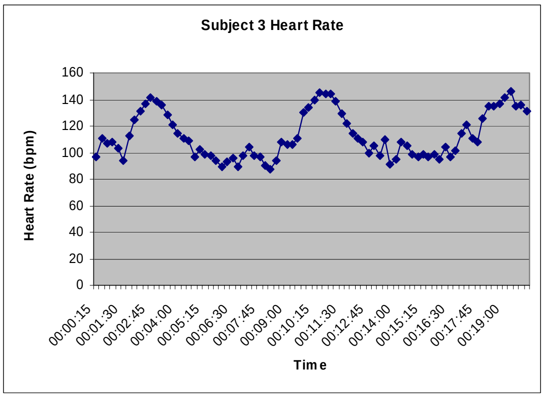


Figure A31.4

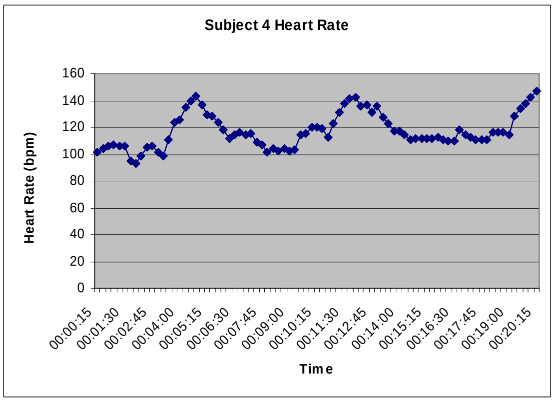


Figure A31.5

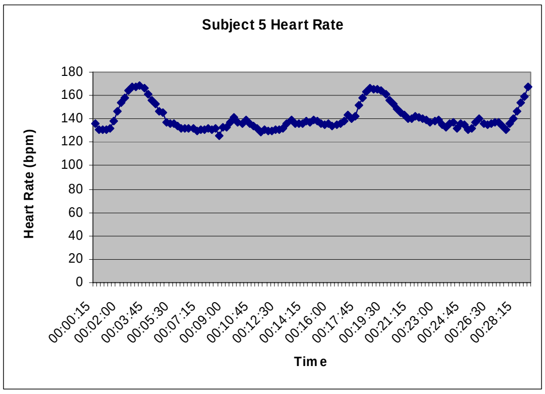


Figure A31.6

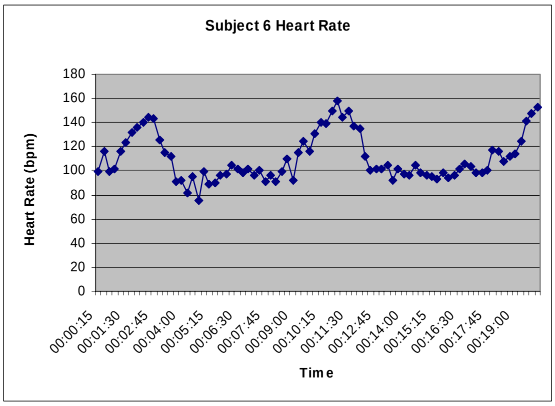


Figure A31.7

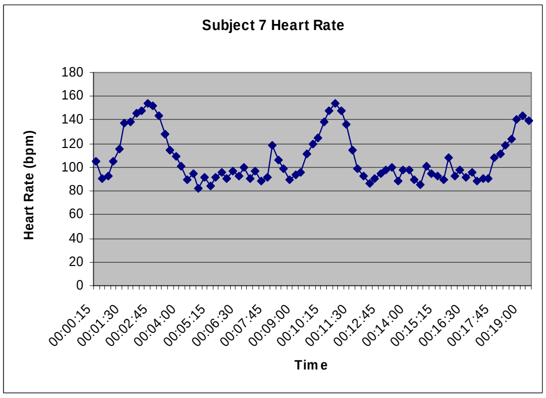


Figure A31.8

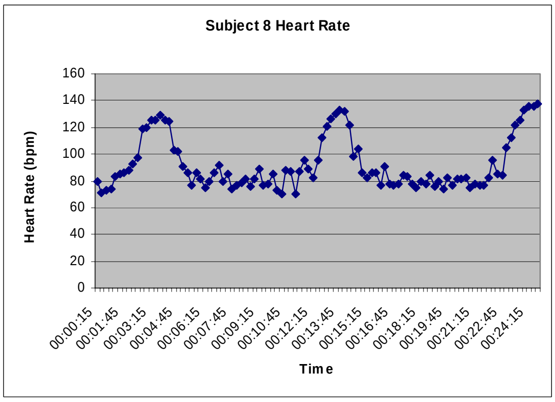
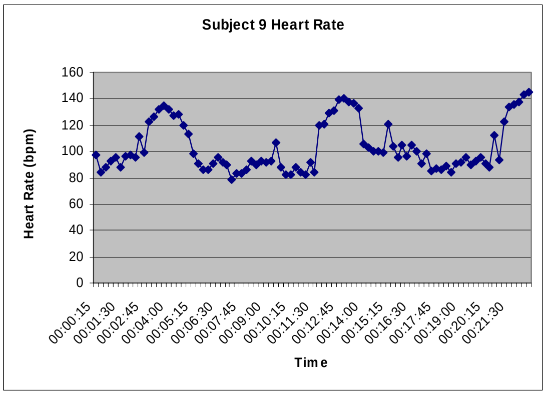


Figure A31.9


Subject 9 Heart Rate
Heart Rate (bpm)
160
140
120
100
80
60
40
20
0
00:00:15
00:01:30
00:02:45
00:04:00
00:05:15
00:06:30
00:07:45
00:09:00
00:10:15
00:11:30
00:12:45
00:14:00
00:15:15
00:16:30
00:17:45
00:19:00
00:20:15
00:21:30
Time

APPENDIX NO. 32:
BAGGAGE HANDLERS OXYGEN CONSUMPTION

Figure A32.1

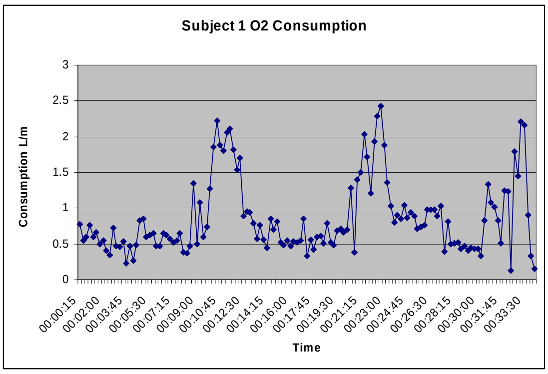


Figure A32.2

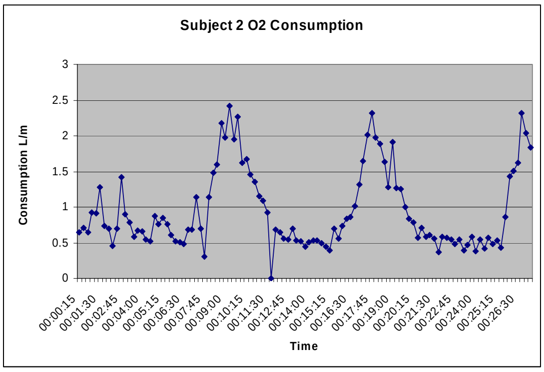


Figure A32.3

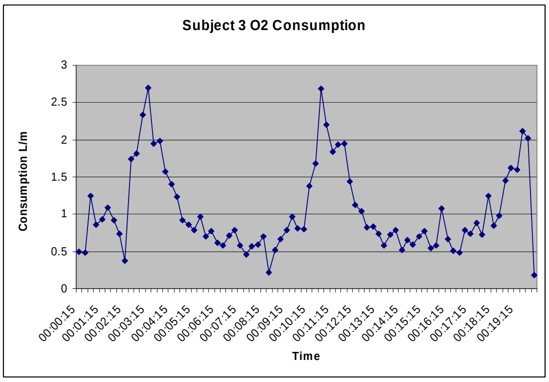


Figure A32.4

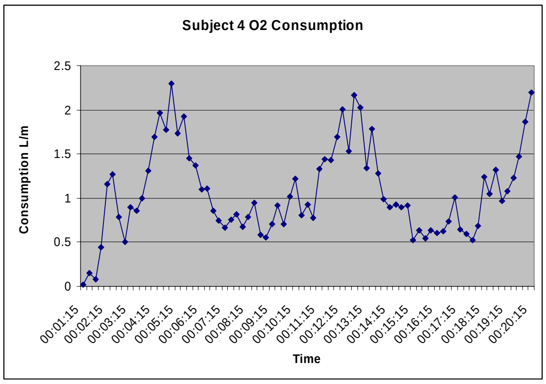


Figure A32.5

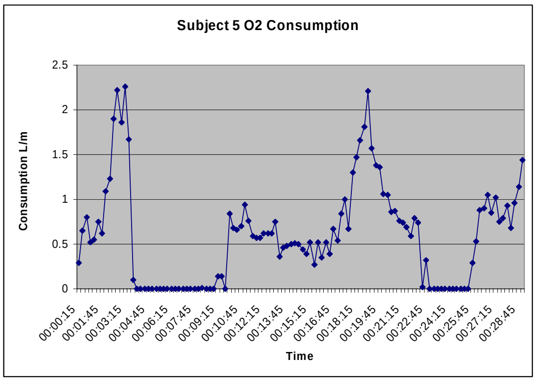


Figure A32.6

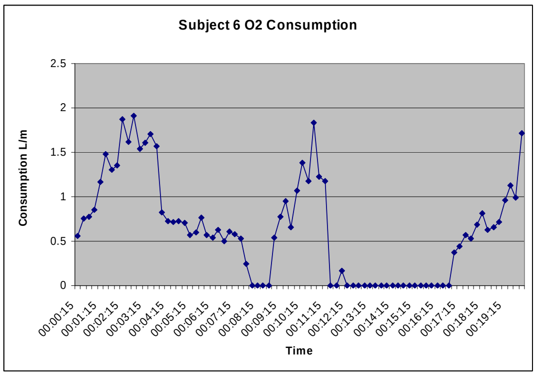


Figure A32.7

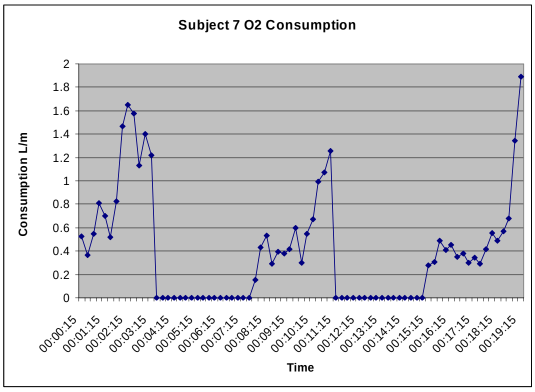


Figure A32.8

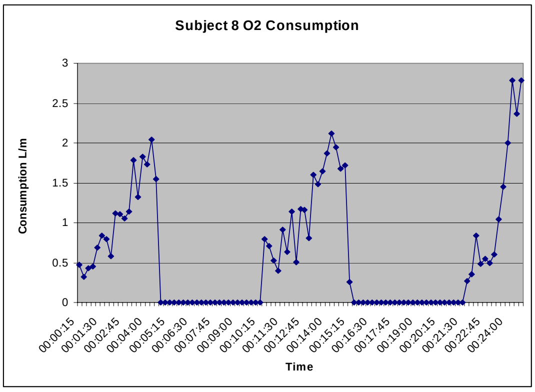
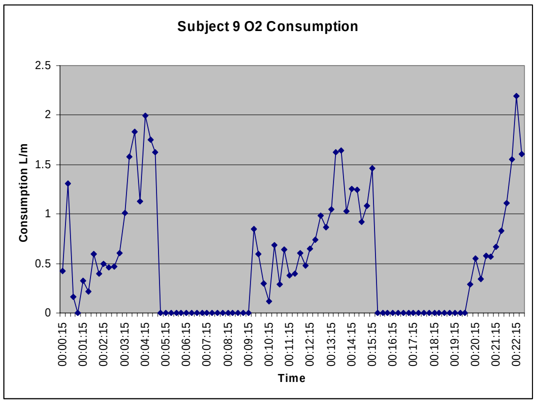


Figure A32.9



APPENDIX NO. 33:

NATIONAL SAFETY COUNCIL OF AMERICA, INTERNATIONAL AIR TRANSPORT EXECUTIVE, MEETING AGENDA JANUARY 1996

AVIATION GROUND SAFETY
A NEW EMPHASIS FOR THE FUTURE

PROGRAM

Monday, 22 January 1996

Registration: 1630 to 1830 hours.

Tuesday, 23 January

Registration: 0700 to 0800 hours.

Executive Committee Meeting

0800 hours

1. Call to order
2. Emergency Evacuation Instructions
3. Self introduction of Members and Guests
4. General Chairman's Welcome
5. Press Officers Report *(Norm Hogwood)*
6. Committee reports:
   (a) Membership *(H Legdeur)*
   (b) Programs *(L Denker)*
   (c) Project Planning *(K Frommelt)*
   (d) Handbook Revision *(G Hayes)*
   (e) Legal *(D Peitsch)*
   (f) Ergonomics *(G Dell)*
   (g) Environmental *(J Page)*
   (h) Occupational Health Hazards *(J Prescott)*
7. Section Administrators Report *(B J Dembski)*
8. IATA Representative report
9. Standards Liaison report *(J von Hoff)*
10. Treasurer report *(B Douglass)*
11. Secretary Comments *(M Paice)*
12. Newsletter Editors Report *(A Steele)*
13. Vice General Chairman's report/future meetings *(D Pietsch)*
14. General Chairman's report *(B Douglass)*
15. Old Business
16. New Business

1130 hours Adjourn

APPENDIX NO. 34:

SUMMARY REPORT TO CALGARY ARTEX WORKSHOP JUNE 20, 1996

SUMMARY REPORT ON

BAGGAGE HANDLER BACK INJURY WORKSHOP

CALGARY June 20, 1996

1. GENERAL

As part of the ARTEX/VIOSH Australia research into the causes and prevention of airline baggage handler back injuries, a workshop was held as part of the Calgary Artex Conference to bring together the opinions of airline management personnel. There were 25 attendees representing 22 aviation industry organisations from 10 countries. A list of participants is included at Attachment No.1.

Participants were divided into workgroups to address the above topic under the following sub-categories.

- Environment
- Load
- Task
- Human Factors

2. WORKGROUP SUMMARIES: RISK FACTORS

The following briefly outlines the key aspects of each workgroups discussions.

2.1 ENVIRONMENT.

The group considered the most significant environmental risk factor leading to injuries was the design of the narrow-bodied aircraft baggage compartment. During preliminary discussions, is was noted that the design had not altered since the advent of heavy jet transport aircraft. Only the relatively recent, but limited advent of stacking systems (eg ACE and sliding carpet) have attempted to re-engineer this confined workspace.

Other environment factors considered to lead to back injuries were poor baggage cart and baggage transfer system design as well as poor ticket counter design.

2.2 LOAD.

This group felt that the greatest risk factor was the weight and size of luggage. It was noted the NIOSH lifting standard was an unaided maximum lift of 51lb (pound), but the airline standard suggested 70 lb (pound), although most agreed the airline standard was hardly ever enforced and heavier baggage was frequently accepted into the airline systems.

An equally significant issue was considered to be the size of baggage and cargo. Often oversize, large, bulky, awkward items were accepted as general cargo or baggage and these caused significant manual handling risk when loaded into narrow-bodied aircraft.

2.3 TASK.

The group that reviewed task-related issues, considered there were four high risk baggage handling tasks:

- transfer of baggage from the scales to the delivery belt at ticket counters,
- loading containers and barrows (trolleys) in the baggage sortation room,
- transferring baggage, (containers and trolleys) on the tarmac outside the aircraft and,
- moving and stacking baggage and cargo in the baggage compartments of narrow bodied aircraft.

2.4 HUMAN FACTORS.

The most significant human-related risk factor was considered to be the age and physical stature of the individuals.

- Due to the confined space of narrow-bodied aircraft baggage compartments, tall people were considered to be at greater risk that shorter persons.
- Age was considered to be a factor because the average age of baggage handlers was thought to be increasing as staff turnover in the modern economic climate has reduced significantly. Where baggage handlers in the past left the area after a few years, it is not uncommon now for most baggage handlers to remain in the role until retirement in their late 50's or even 60's.

Poor employee morale was also considered to be a significant issue when leading to increase in injury reporting. It was thought that during periods of low employee morale, baggage handlers were more inclined to report minor back injuries which would otherwise go unreported. However, this was not necessarily considered to be a negative factor since early intervention to address minor injuries has been shown to be a better rehabilitation strategy.

Another key factor is employee fatigue. Often long shifts are worked and due to recent productivity improvement drives which reduced the numbers in the overall workforce, baggage handlers get no opportunity for rest during the course of the shift, and are required to hurry from one aircraft to another to meet ever increasing schedule demands.

3. SUGGESTED SOLUTIONS.

3.1 ENVIRONMENT.

The group determined that there were two possible solutions to improve the working environment:

- Development and testing of reliable, mechanical loading systems for narrow-bodied aircraft which significantly reduced or eliminated the manual handling risk,
- development of practical containerisation solutions foe narrow-bodied aircraft.

While the ACE and sliding carpet systems had been reported as reliable, there was little or no research in the past as to their effectiveness from an injury prevention perspective. There is a clear need for more research into the effectiveness of these systems.

Other than some trial developments of containerisation systems for narrow-bodied aircraft in the early 90's in Sweden, there has been very few attempts to provided such systems. It was noted that Airbus Industrie had developed such a system for the A319/A320/A321 but virtual no airlines purchasing these aircraft had purchased the option.

3.2 LOAD

Consistent airline policy across the industry limiting the weight and size of baggage which will be excepted for uplift needs to be introduced. Manual handling regulations in most western industrial societies already provide such limitations, but the airline industry has generally ignored these regulations.

3.3 TASK

All solutions for the manual handling task suggested by the group, hinged on automation. Baggage transfer belts at all check-in counters, automatic baggage sorting systems, mechanical lifting aids where manual handling tasks cannot be eliminated, containerisation systems and/or stacking systems (eg. ACE and sliding carpet) for all narrow-bodied aircraft.

3.4 HUMAN FACTORS

Intervention strategies targeting the individual, with the most likely chance of reducing baggage handler back injuries were supervised general fitness and wellness programs, control of shift duration, manual handling frequencies, and task rotation.

There is a need for further research into the effect of the changing shift patterns, reduced manning levels and increased flight schedules.

4. PROPOSED ACTION.

4.1 The undersigned will prepare a detailed journal article covering the outcomes of this workshop for publication in a refereed safety journal eg Ergonomics Today, or The Journal of Safety Science and/or appropriate trade journals eg Airports International or Airport Support.

4.2 In association with the Atlanta ARTEX conference in 1997, the ergonomics sub-committee will convene a workshop involving all major aircraft manufacturers, aircraft loading/stacking system manufacturers, key ground support equipment manufacturers, airlines and baggage handler labour unions, so that system-based, design and engineering solutions can be explored.

4.3 Due to the general lack of awareness of this issue across the industry, the ergonomic sub-committee on behalf of ARTEX will approach the US ATA and IATA to put the findings of the ARTEX work to date in this area to airline senior executives. This will require preparation of material for publication in the IATA and ATA journals.

4.4 To elevate the issue in appropriate engineering and scientific communities, ARTEX should run design based competitions amonst university engineering and science students. Ideally, universities on all continents should be invited to participate. The ARTEX Ergonomic Sub-committee should coordinate the competition and assess the submissions. ARTEX member airlines could be approached to donate travel prizes.

Attachment No. 1

ATTENDEES

NAME	**ORGANISATION**
Douglas Briggs	The Boeing Co.
Ray Wells	British Airways
Dirk Scott	Hong Kong Air Terminal Services
Jim Von Der Linn	Scandinavian Belly Loading Co.
Jim Braymen	Dynair
Gary Hirsch	Evergreen International Aviation
John Flynn	American Airlines
Russ Timpson	Virgin Atlantic
Michael Lueck	Airborne Express
Dieter Peitsch	Delta Airlines
Stephanie Benay	Canadian Regional Airlines
Elaine Parker	Canadian Regional Airlines
Bill Douglass	Consultant Southwest Airlines
Paddy Sullivan	Aerlingus
Melanie Costly	Canadian Airlines
Geoff Hayes	Canadian Airlines
Bill Grimes	Johnson & Higgins
Bill Jaggi	Trans World Airlines
Sandy Gross	BF Goodrich Aerospace
Harrie Legdeur	KLM
Bill Carlyon	The Boeing Co
Barbra-Jean Lomastro	National Safety Council
Norman Hogwood	Air New Zealand
Geoff Dell	Protocol Safety Management
Dave Thompson	Consultant

APPENDIX NO. 35:

BAGGAGE HANDLER BACK INJURIES: A PROJECT UPDATE - Presentation at the National Safety Council Of America, International Air Transport Executive Meeting, Sydney January 1996

BAGGAGE HANDLER BACK INJURIES:

A PROJECT UPDATE

presented by

GEOFF DELL
MANAGER SAFETY - GROUP AIRPORT OPERATIONS
QANTAS AIRWAYS

at

ARTEX CONFERENCE, SYDNEY - JANUARY 25, 1996

INTRODUCTION

In 1994, with the support of ARTEX and the Australasian Airline Ground Safety Council (AAGSC), a major project was commenced to investigate the problem of back injuries in the airline baggage handler work force. The project was designed to tackle the issue from several angles: a review of existing technologies, a survey of opinion of the aviation ground safety fraternity (ARTEX and AAGSC representatives), surveys of baggage handlers' opinion, and an investigation of alternative solutions and new technologies (with the help of the aircraft and ground support equipment manufacturers). This paper primarily reports on the preliminary responses from the aviation ground safety professionals.

The survey questionnaire seeking opinion of the ground safety professionals was circulated to 32 ARTEX and AAGSC members in June, 1995. There have only been 12 responses to date. Data from 11 of those airlines have been included in this paper. These airlines employed 8958 baggage handlers in 1994 and operated a total of 350 heavy jet transport aircraft of 19 different types. One response was from an all freight airline that does not carry baggage. Data from this operator has not been included in this paper.

Preliminary face to face meetings were held in 1995 with key staff of the following aircraft manufacturers; Boeing, McDonnell Douglas, Avro and Airbus Industrie. Discussions were held with Fokker staff by teleconference. While all manufacturers showed an interest in the back injury subject, it was apparent the issue had not been raised with them before, and they were all keen to obtain quantitative data on the cost of these injuries and the magnitude of the problem.

At the Memphis ARTEX conference in 1994, I related that anecdotal evidence then available, indicated that back injuries to airline baggage handlers cost the aviation industry millions of dollars per annum and some airlines had over 20% of their baggage handler workforce absent due to back injuries at any one time. Accordingly, the survey of safety professionals included a number of questions intended to validate the anecdotal evidence and quantify the costs. Only 10 of the 11 safety professionals from the passenger airlines were able to provide cost information for 1994 (only 9 each for 1993 and 1994).

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A number of other survey recipients who have not responded, indicated at the time they received the survey that they would be unable to obtain cost information from their organisations. This, no doubt, is one of the reasons for the low number of airline safety professionals who have responded to the survey. Unless the majority of ARTEX safety professionals can extract the real costs of those injuries which have occurred, then it may be difficult, if not impossible, to justify to the aircraft and equipment manufacturers, the expenditure which will be needed to eliminate such injuries in the future.

As I stressed at the 1994 Memphis conference, Occupational Health and Safety Professionals in the aviation industry have an obligation to take up the challenge to address this issue. There is a need to seek real solutions to the problem and address aircraft and ground equipment design and serviceability and develop more realistic international baggage and cargo weight and size standards. If we don't achieve a satisfactory result, the labour force will impose sanctions on the industry which will be far less palatable and more expensive than any solutions our profession may consider, however complex and hi-tech they may be (*Dell 1994*).

PRELIMINARY RESULTS OF THE SURVEY OF SAFETY PROFESSIONALS

RATES OF BAGGAGE HANDLER BACK INJURY OCCURRENCE AND COST PER INJURY

In an effort to identify the magnitude of the back injury problem, safety professionals were asked to provide some information about their organisations for the 3 years; 1992, 1993 and 1994, in the following categories: The number of baggage handlers employed annually, the average hours worked by baggage handlers per week, the number of baggage handler lost time back injuries annually and the annual cost of those injuries. Tables 1 to 4 show their responses. This information was used to calculate annual Lost Time Frequency Rates (LTFRs) per 10^6 hours worked for the study group.

1992 Company		1993 Company		1994 Company	
1	480	1	535	1	600
2	1800	2	2000	2	2500
3	N/R	3	N/R	3	519
4	N/R	4	360	4	360
5	162	5	167	5	161
7	280	7	270	7	360
8	465	8	455	8	545
9	1623	9	1564	9	1643
10	699	10	762	10	790
11	170	11	180	11	180
12	1400	12	1100	12	1300
TOTAL	**7079**	TOTAL	**7393**	TOTAL	**8958**

TABLE 1

NUMBER OF BAGGAGE/ HANDLERS EMPLOYED

3

Where any organisation could not provide information in one or more of the categories in any year, all of that organisation's data was removed from the calculation for that year. This permitted reliable LTFRs (see Figure 1) and average injury costs (see Figure 2) to be calculated to enable a comparison of performance from year to year.

Company	1992	1993	1994
1	37.5	37.5	37.5
2	42	45	49
3	42	42	42
4	48	48	48
5	50	50	48
7	37	40	35
8	20	22	23
9	37.5	37.5	37.5
10	48	48	48
11	38.5	38.5	38.5
12	52	52	52
AVERAGE	**41.1**	**41.8**	**41.7**

TABLE 2
AVERAGE HOURS WORKED PER WEEK PER BAGGAGE HANDLER EMPLOYEE

Figure 1 graphs the LTFRs calculated from the complete respondent data sets. Baggage handler LTFRs remained almost constant across the 3 years (39 for 1992, 43 for 1993 and 42 for 1994). This would suggest that the industry has not had any real impact on reducing the instance of back injuries during the period of the study.

Also, it is interesting to note that these LTFRs suggest that for every 500 baggage handlers employed in the study group organisations, on average 41(8%) (average of 39, 43 and 42)

Company	1992	1993	1994
1	19	19	19
2	104	163	266
3	10	21	15
4	N/R	N/R	N/R
5	13	13	20
7	22	16	19
8	20	30	39
9	206	210	209
10	N/R	N/R	N/R
11	1	2	1
12	130	110	120
TOTAL	**525**	**584**	**708**

TABLE 3
NUMBER OF BAGGAGE HANDLER LOST TIME BACK INJURIES

4

1992 Company	$US	1993 Company	$US	1994 Company	$US
1	76000	1	90133	1	143200
2	1200000	2	1387500	2	1500000
3	N/R	3	N/R	3	6500
4	N/R	4	N/R	4	N/R
5	26000	5	26000	5	40000
7	121000	7	104000	7	133000
8	17000	8	23000	8	31000
9	118012	9	328527	9	256433
10	69345	10	65110	10	67520
11	0	11	0	11	0
12	1000000	12	1050000	12	1000000
TOTAL	**2627357**	TOTAL	**3074270**	TOTAL	**3177653**

TABLE 4
ANNUAL COST OF BAGGAGE HANDLER LOST TIME BACK INJURIES

experienced lost time back injuries each year, if a 40 hour week and 50 week year is assumed (ie 10^6 hours worked = 500 people x 40 hours x 50 weeks).
Figure 2 shows that when average costs of baggage handler back injuries were calculated from the data provided by respondents, there was again a slight improvement in 1994 ($US3663) when compared to 1993 ($US4204) and 1992 ($US4019).

The reasons for the slight improvement in LTFRs and costs in 1994 has not become apparent in this study to date.

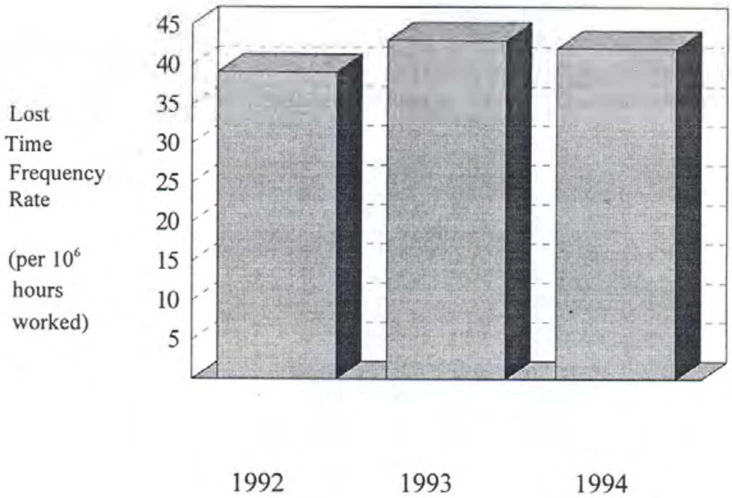

FIGURE 1

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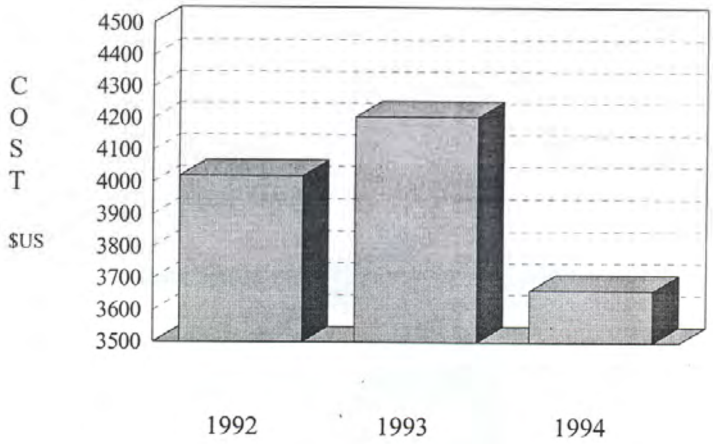

FIGURE 2
AVERAGE COST ($US) PER BACK INJURY

CAUSES OF BAGGAGE HANDLER BACK INJURIES AND SOME POSSIBLE SOLUTIONS

The Safety Professionals were asked to rank the following workplaces in order from that which they considered were most likely to cause a back injury, to those which were least likely. The work places were: Baggage check-in; Baggage make-up room; Inside narrow body aircraft; Inside wide body aircraft bulk hold, and; Outside aircraft on the ramp. Table 5 shows that 6 of the 11 respondents felt that the highest injury risk location to be "Inside Narrow Body Aircraft", and this is consistent with earlier studies of this matter (*ARTEX (1980) & Dell (1994)*). It is of interest to note that none of the respondents felt that working inside the bulk hold of wide-bodied aircraft presented a greater risk of injury than working in the baggage make-up room, outside the aircraft on the ramp, or in the baggage check-in area.

As Table 6 shows, 6 respondents in the group selected "Baggage Check-in" as least likely to cause baggage handler back injuries. Again it is worthy of note that none selected "Inside Narrow Body Aircraft" as that least likely to cause injury.

With regard to which baggage handling tasks were considered most likely to cause back injury, 9 of the 11 respondents selected "Stacking Baggage inside the Baggage Compartment of Narrow Body Aircraft" as one of their top 5 high risk tasks (see Table 7). This was closely followed by "Pushing Baggage from the Doorway into the Baggage Compartment of Narrow Body Aircraft" (8 responses). "Transferring Baggage from a Trailer directly into a Narrow Body Aircraft" and "Pushing and Pulling Containers and Pallets inside Wide Body Aircraft

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when Equipment is Broken" were equally ranked as the third most likely injury causation tasks (7 responses each).

a) Baggage Check-in 1	b) Baggage Make-up Room 2	c) Inside Narrow Body Aircraft 6
d) Inside Wide Body Aircraft Bulk Hold 0	e) Outside Aircraft on the Ramp 2	

TABLE 5
MANUAL HANDLING LOCATIONS RANKED *MOST* LIKELY TO CAUSE INJURY

a) Baggage Check-in 6	b) Baggage Make-up Room 0	c) Inside Narrow Body Aircraft 0
d) Inside Wide Body Aircraft Bulk Hold 3	e) Outside Aircraft on the Ramp 2	

TABLE 6
MANUAL HANDLING LOCATIONS RANKED *LEAST* LIKELY TO CAUSE INJURY

Ten of those surveyed indicated that baggage handlers in their organisations were required to lift baggage weighing in excess of 32kgs(70lbs). It is also significant that 9 of the 11 respondents considered such heavy baggage to be a significant injury risk to baggage handlers.

POSSIBLE SOLUTIONS TO THE BACK INJURY PROBLEM

Heavy Baggage

Table 8 summarises the preferences of the survey group for possible solutions to the risk of injury caused by heavy baggage. Seven respondents felt that there was a need for the introduction of baggage and cargo weight limits, while 4 felt that the industry should educate the travelling public about the problem of heavy baggage. It is of interest to note that only 3 felt that the industry should provide mechanical assistance devices for lifting heavy baggage.

Australian experience with using passenger education programs to tackle the heavy baggage issue has been one of mixed success. Posters and warning material at check-in locations has elevated the profile of the issue, but has had little or no impact on the frequency of heavy baggage being presented to the airline for uplift. Control of the heavy baggage risk has relied on compliance with baggage acceptance procedures at check-in locations which require baggage over 32Kg to be re-packed prior to check-in.

Such procedures, while limited in effectiveness like all procedural barriers (and their low position on the hierarchy of Controls (*Department of Labour (1990)*), have been rigorously supported by baggage handling staff who have consistently returned bags over 32Kg to the check-in location for re-packing.

While these procedures have had an impact on exposure to heavy baggage, they do not

a) Lifting baggage on and off scales or conveyor at check-in	1
b) Loading baggage onto trailers in the baggage room	5
c) Loading containers in the baggage room	4
d) Unloading baggage trailers in the baggage room	3
e) Unloading containers in the baggage room	1
f) Pushing and pulling loaded baggage trailers, containers and pallet dollies	5
g) Transferring baggage from a trailer to a mobile belt positioned at an aircraft cargo door	1
h) Transferring baggage from a trailer directly into a narrow body aircraft through the cargo door	7
i) Pushing baggage from the doorway into the baggage compartment of a narrow body aircraft	8
j) Stacking baggage inside the baggage compartment of narrow body aircraft	9
k) Pushing and pulling containers and pallets inside wide body aircraft (when equipment is broken etc.)	7
l) Stacking baggage in the bulk hold of wide body aircraft	4

TABLE 7
MANUAL HANDLING TASKS CONSIDERED *MOST* LIKELY TO CAUSE BACK INJURIES

address the risk of injury presented by those bags weighing up to 32Kg. For this reason, there is surely the need to develop mechanical assistance devices or automated systems to eliminate or reduce the injury risk associated with those manual handling tasks listed in Table 7.

Back Support Belts

Safety professionals were asked to indicate whether their organisations had used back support belts as a measure to control back injuries in baggage handlers. Table 9 summarises their responses.

Only 1 reported that a back support belt was used. However, this respondent also reported that introduction of the belts had made no difference to the instance of baggage handler back injuries in that company.

This result is also consistent with the findings of *Perkins and Bloswick (1995)*, who concluded that "*The impact of back belts on the prevention of back injuries due to manual material handling remains unclear*" and "*There is no clear evidence that back belts reduce the incidence or severity of back injuries*". Similar conclusions were also made by *NIOSH (1994)*.

SOLUTIONS	NUMBER OF RESPONSES
Limit Baggage and Cargo Item Weights	7
Educate the Public (re Heavy Baggage Issue)	4
Better Procedures for Acceptance of Baggage/Cargo	3
Provide Mechanical Assistance Devices for Lifting Heavy Baggage	3
Breakdown Heavy Baggage to Acceptable Weights	2
Clearly Identify Heavy Baggage (with a label/tag)	2
Better Training of Staff	1

TABLE 8
POSSIBLE SOLUTIONS TO THE PROBLEM OF HEAVY BAGGAGE & CARGO

Back Care Training

Respondents were asked whether Back Care Training was used as an injury control measure, and if so, what impact had the training had on the instance or severity of back injuries. Table 10 summarises their responses.

It is of interest to note that while 7 of the 11 respondents reported that Back Care Training was provided to staff, none reported that the training had any effect on their back injury rates.

There are many commercially available back care training packages available around the world. It seems that some are in regular use by airlines in attempt to tackle the baggage handler back injury problem. In Australia, some of these programs have been used for many years.

The fact that the LTFR has not appreciably changed over the past 3 years, would suggest that more back care training is unlikely to have a positive effect on injury occurrence.

Company		Type	Improvement
1	No	-	-
2	No	-	-
3	No	-	-
4	No	-	-
5	Yes	Hawkins	None
7	No	-	-
8	No	-	-
9	No	-	-
10	No	-	-
11	No	-	-
12	No	-	-

TABLE 9
USE OF BACK SUPPORT BELTS

Ground Equipment

Eight of the 11 respondents reported that they used ground equipment to reduce the manual handling risk to baggage handlers (see Table 11). Only 1 reported that use of ground equipment had resulted in an improvement in injury occurrence (10%). One of the reasons that others had not reported any similar improvements, may be found in the responses in Table 7 on the question of equipment serviceability. Seven of the 11 respondents indicated that manual handling tasks associated with pushing and pulling baggage containers and pallets were a significant injury risk when equipment was broken or otherwise unserviceable. As suggested in *Dell (1994)*, "*There is no doubt the industry needs to make wholesale improvements to baggage transfer systems maintenance. Airlines need to ensure that similar priority is given to maintenance of loading equipment as is afforded to other aircraft systems.*"

Company		Type	Improvement
1	No	-	-
2	Yes	Basic Warm-up Exercises	None
3	No	-	-
4	No	-	-
5	Yes	Lifting Technique Training	No Response
7	Yes	Lifting Technique Training	None
8	Yes	Lifting Technique Training	No Response
9	Yes	Lifting Technique Training	No Response
10	Yes	Lifting Technique Training	No Response
11	No	-	-
12	Yes	Lifting Technique Training	Not Known

TABLE 10
BACK CARE TRAINING

Baggage Room Design

Table 12 summarises the responses concerning those instances where baggage room re-design had been used to reduce the baggage handling injury risk. Only 3 reported their organisations' having done so. Again, only 1 respondent was able to suggest that a reduction in injury occurrence had occurred.

Company		Type	Improvement
1	No	-	-
2	Yes	Narrow Body Portable Roller Beds	None
3	Yes	Conveyor Belts, Forklifts, Pallet Loaders	None
4	No	-	-
5	Yes	Belt Loaders	10%
7	No	-	-
8	Yes	Belt Loaders	No Response
9	Yes	Container Loaders, Belt Loaders	Not Known
10	Yes	Conveyor Belts, Forklifts, Pallet Loaders	No Response
11	Yes	Conveyor Belts	Not Known
12	Yes	Narrow Body Portable Roller Beds	None

TABLE 11
GROUND EQUIPMENT USED TO REDUCE MANUAL HANDLING

There is no doubt that state of the art baggage sortation systems today, do not take manual handling injury risk into consideration other than by a very rudimentary ergonomic compromise. Hi-tech computerised systems deliver baggage to the location where the load for particular flights are being handled, but leave the actual loading and stacking tasks to manual handling. The new systems at Denver Stapleton, Sydney International, Brisbane International, Melbourne International and Wellington are examples. With these systems, the design of conveyor belts at the worker interface uses average heights and distances to try to cope with the ergonomic problems presented.

Company		Type	Improvement
1	No	-	-
2	No	-	-
3	No	-	-
4	No	-	-
5	Yes	Carousel Belts	20%
7	Yes	Automatic Baggage Sorting System	Not Known
8	No	-	-
9	No	-	-
10	No	-	-
11	No	-	-
12	Yes	Ergonomic re-design of existing carousal	Not Known

TABLE 12
HAS BAGGAGE ROOM DESIGN BEEN ADDRESSED AS A POSSIBLE CONTROL MEASURE?

11

Unfortunately, this is not likely to be an easy matter to resolve. Not only is there the difficulty of designing adequate mechanical assistance devices to load baggage containers and barrows, although this task should not be insurmountable, there is a definite reluctance of airport designers and builders to give the matter the credence it deserves.

Company		Type	Under Test/ Investigation	Improvement
1	No	-	-	-
2	No	-	Yes	-
3	Yes	Sliding Carpet		10%
4	No	-	-	-
5	No	-	-	-
7	No	-	-	-
8	No	-	-	-
9	No	-	-	-
10	No	-	-	-
11	No	-	Yes	-
12	No	-	-	-

TABLE 13
USE OF NARROW BODY IN-PLANE BAGGAGE SYSTEMS

At a recent Australian airline industry meeting with project officers of the airport authority, specifically to discuss design aspects of the new Melbourne International baggage sortation system, project engineers were bemused even at the concept of making the geometry of delivery belts and container heights fully adjustable to optimise the ergonomic advantage for

MEASURES		f
Procedural or Person Focused Solutions		
Better Training and Education of Baggage Handlers		9
Introduce Warm-up Exercises		3
Allocate/Employ Staff to Meet Job Needs		2
Improve supervision		1
Slow the Baggage Handling Process Down		1
Introduce Back Belts		1
	Total	18
Engineering or System Focused Solutions		
Limit Baggage Weights		6
Redesign Baggage Handling Systems		3
Develop In-plane Baggage/Cargo Stacking Systems		2
Introduce Robotics to Eliminate Manual Handling		1
Better Maintenance of Equipment		1
Redesign Aircraft		1
	Total	14
Other Suggestions		
Conduct More Scientific Studies of Baggage Handling tasks		4

TABLE 14
SUGGESTED MEASURES TO REDUCE BACK INJURIES

all individuals. The idea of providing mechanical lifting aids or automating the manual handling tasks was treated as if in the realms of science fiction.

Airline safety professionals clearly have a difficult task ahead to make in-roads into this problem. However, unless design engineers are convinced of the seriousness of the baggage handling injury issue, they will continue to construct these critical manual handling workplaces from concrete and ignore the basic ergonomic needs of all but the average proportioned individual baggage handler.

Narrow Body In-plane Systems

Table 13 shows that only 1 of the respondent airlines had installed a baggage system in narrow body aircraft, with a positive effect of a 10% improvement in injury occurrence.

In a later part of this project, the opinion of baggage handlers who have extensively used narrow body in-plane systems will be sought. Also, using the University of Michigan 3D Static Strength Computer model, video footage will be analysed of baggage handlers carrying out loading tasks using the in-plane baggage stacking systems of 2 airlines who have already installed such systems. This work will be carried out early in 1996 and reported at a subsequent ARTEX conference.

Suggested Future Control Measures

Table 14 is a summary of Safety Professionals' responses to the question: What measures do you believe will effectively reduce the instance of baggage handler back injuries in future?

In all, 12 different possible control measures were identified. These were evenly divided: six focused on the individual and baggage handling procedures and six on engineering or system focused solutions. However, the individual/procedural solutions were favoured by slightly more respondents (18 selections) on balance, than the engineering/system solutions (14 Responses).

"Better training of baggage handlers" was the most highly favoured response overall (9 responses) and "Limit Baggage Weights" was the most highly favoured engineering/ system solution (6 responses). Introduction of Warm-up exercises was equally favoured with the Redesign of Baggage Handling Systems (3 responses each).

Four respondents felt there was a need for more research into the baggage handling injury problem. Although this is not actually a control measure in itself, more research may lead to better control measures in future. It would also have the effect of further raising the profile of the baggage handler back injury issue. It is likely that few safety professionals would argue the benefit of such a result.

As mentioned above, the Hierarchy of Controls (*Department of Labour (1990)*, would tend to suggest the engineering or system focused control measures would probably having a better likelihood of causing a sustained improvement in back injury causation. Therefore, it is on these solutions that this project will concentrate its investigations in future.

CONCLUSION

LTFRs calculated from the data from the survey of safety professionals suggest that the instance of baggage handler back injuries is almost constant over the 3 years 1992 to 1994. Also, the average cost per back injury is similarly almost constant, suggesting that the average severity of injury is not significantly changing either. While some comfort may be taken in the fact that there does not appear to be a worsening trend, neither is the trend improving.

The survey shows that over $US 3million was lost due to baggage handler back injuries in 1994 in only 10 airlines. Also, around 8% of baggage handlers suffered back injuries each year of the study period.

Accordingly, there is little doubt that the industry must find real and long term solutions to the causation of baggage handler back injuries.

The key injury prevention findings of this study, and in accord with the hierarchy of controls (*Department of Labour (1990)*), those which will dictate the future emphasis of this project, are:

1. Re-design of Baggage Handling Systems to Reduce or Eliminate Manual Handling risks, and

2. The Need for Limitation to be placed on Baggage Weights.

Also, the strong preference of surveyed safety professionals for better training and education of baggage handlers, suggests the need for further research in this aspect of the back injury problem.

One area of concern highlighted by the survey is the difficulty some safety professionals obviously had in quantifying the costs of back injuries and benefits of some of the recognised injury control measures. If this shortcoming is indicative of our profession generally, then it speaks volumes for our ability, or perhaps inability, to influence our business masters. In future, if we cannot support our efforts with basic business measures, such as cost, then it is highly unlikely that ARTEX work to eliminate injuries in airline ground operations will be taken seriously. In the context of this Back Injury Project, the support and commitment of the aircraft and equipment manufacturers, who will be required to take much of the remedial design action in the long term, will surely be jeopardised without accurate cost data from a bigger sample of airlines, to quantify the size of the industry's baggage handler back injury problem.

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APPENDIX NO. 36:

BAGGAGE HANDLER BACK INJURIES PROJECT STATUS REPORT – ATLANTA JANUARY 1997

BAGGAGE HANDLER BACK INJURIES
PROJECT STATUS REPORT

Presented by

GEOFF DELL
M APP SCI (OHS), GRAD DIP OHM, FSIA, MISASI
ARTEX BACK INJURY PROJECT CO-ORDINATOR

1. INTRODUCTION

In 1994, with the support of ARTEX and the Australasian Airline Ground Safety Council (AAGSC), a major project was commenced to investigate the problem of back injuries in the airline baggage handler work force. The project was designed to tackle the issue from several angles: a survey of opinion of the aviation ground safety fraternity (ARTEX and AAGSC representatives), surveys of baggage handlers' opinion, a review of existing technologies and an investigation of alternative solutions (with the help of the aircraft and ground support equipment manufacturers). This paper summarises progress to date.

Anecdotal evidence available in 1994 (Dell 1994), indicated that back injuries to airline baggage handlers cost the aviation industry millions of dollars per annum. Also, some airlines had over 20% of their baggage handler workforce absent due to back injuries at any one time. In 1995 preliminary meetings with key staff of Boeing, McDonnell Douglas, Avro, Fokker and Airbus Industrie revealed that while they were interested in the back injury subject, it was apparent the issue had not been raised with them before. All of these manufacturers requested quantitative data on the cost of these injuries and the magnitude of the problem.

Since there was no reliable data available, the first phase of the project, the survey of safety professionals, was designed, in part, to validate the anecdotal evidence and quantify the costs.

2. SURVEY OF AIRLINE SAFETY PROFESSIONALS

Sixteen airlines provided useable data in this phase of the project. The survey captured information relating to back injuries in airline baggage handler workforce from 1992 to 1994. The results were as follows:

Table 1
Quantifying the Back Injury Problem

	1992	1993	1994
No of Baggage Handlers	19430	30257	29099
Av. Hours Worked/ Person	38.0	38.4	38.4
No of Lost Time Injuries	1570	2408	2405
Annual Cost ($US)	$17,639,857	$23,697,170	$21,710,953
Lost Time Injury Frequency (per 10^6 hours worked)	42.5	41.5	43.5
Average Cost Per Back Injury	$11,236	$9841	$9027

It is interesting to note that while the cost per injury was reducing, the actual numbers of injuries increased over the period. Also, the relatively constant lost time frequency rates would suggest any pre-existing injury prevention programs had been ineffective at reducing the instance of lost time baggage handler back injuries.

This data removes any doubt about the industry's need to take positive injury prevention steps. If the legislative requirements to provide safe work places, or the moral duty of care to protect the well being of employees, are not incentive enough, then the ongoing high costs of back injuries should alone dictate the need.

2

In addition to quantifying the magnitude of the problem, the survey sought to capture the airline safety professionals' opinions on the causes and possible solutions to the injury problem.

The Safety Professionals were asked to rank the following workplaces in order from that which they considered were most likely to cause a back injury, to those which were least likely. The work places were: Baggage check-in; Baggage make-up room; Inside narrow body aircraft; Inside wide body aircraft bulk hold, and; Outside aircraft on the ramp. Ten respondents felt that the highest injury risk location to be "Inside Narrow Body Aircraft", and this is consistent with earlier studies of this matter (*ARTEX (1980) & Dell (1994)*).

With regard to which baggage handling tasks were considered most likely to cause back injury, again 14 respondents selected "Stacking Baggage inside the Baggage Compartment of Narrow Body Aircraft" as one of their top 5 high risk tasks. This was closely followed by "Pushing Baggage from the Doorway into the Baggage Compartment of Narrow Body Aircraft" (11 responses). "Transferring Baggage from a Trailer directly into a Narrow Body Aircraft" and "Pushing and Pulling Containers and Pallets inside Wide Body Aircraft when Equipment is Broken" were equally ranked as the third most likely injury causation tasks (9 responses each).

Fifteen of those surveyed indicated that baggage handlers in their organisations were required to lift baggage weighing in excess of 32kgs (70lbs). It is also significant that 14 of them considered such heavy baggage to be a significant injury risk to baggage handlers.

So it is clear from the responses that the Airline Safety Professionals consider these areas prime targets for the industry's injury prevention effort.

Indeed, ten respondents felt that there was a need for the introduction of baggage and cargo weight limits.

The Australasian experience in using passenger education programs to tackle the heavy baggage issue has been one of mixed success. Posters and warning material at check-in locations has elevated the profile of the issue, but has had little or no impact on the frequency of heavy baggage being presented to the airline for uplift. Control of the heavy baggage risk has relied on compliance with baggage acceptance procedures at check-in locations which require baggage over 32kg to be re-packed prior to check-in. Although these procedures are low in the hierarchy of Controls (*Department of Labour (1990)*) and are limited in effectiveness, they have been rigorously supported by baggage handling staff (Dell 1996).

Mechanical assistance devices or automated systems are clearly needed to eliminate or reduce the injury risk associated with traditional manual baggage handling tasks.

Twelve respondents reported that Back Care Training was provided to staff, with only 2 reporting a positive effect on their back injury rates. Nonetheless, training was the most highly favoured solution. Ten respondents still favoured "Better Training" as their preferred solution. The fact that the LTFR has not appreciably changed over the past 3 years, during which back training programs were being conducted by the majority of the respondent airlines, this would suggest that "more" back care training is unlikely to have a positive effect on injury occurrence.

Eleven respondents reported that they used ground equipment to reduce the manual handling risk to baggage handlers. Only 1 reported that use of ground equipment had resulted in an improvement in injury occurrence (10%). Nine indicated that manual handling tasks associated with pushing and pulling baggage containers and pallets were a significant injury risk when equipment was broken or otherwise unserviceable. As suggested in *Dell (1994)*, *"There is no doubt the industry needs to make wholesale improvements to baggage transfer systems maintenance. Airlines need to ensure that similar priority is given to maintenance of loading equipment as is afforded to other aircraft systems."*

3

With regard to baggage room design, there is no doubt that state of the art baggage sortation systems today do not take manual handling injury risk into consideration other than by a very rudimentary ergonomic compromise. Hi-tech computerised systems deliver baggage to the location where the load for particular flights are being handled, but leave the actual loading and stacking tasks to manual handling. The new systems at Denver Stapleton, Sydney International, Brisbane International, Melbourne International and Wellington International are examples. With these systems, the design of conveyor belts at the worker interface uses average heights and distances to try to cope with the ergonomic problems presented.

Airline safety professionals clearly have a difficult task ahead to make in-roads into this problem. Unless design engineers are convinced of the seriousness of the baggage handling injury issue, they will continue to construct inappropriate baggage rooms which require manual baggage handling, without provision for mechanical assistance or allowance for adjustment of workplace geometry to meet individual needs.

3. CALGARY WORKSHOP

A workshop was held as part of the Calgary Artex Conference in 1996 to bring together the opinions of airline management personnel. Twenty five attendees representing 22 aviation industry organisations from 10 countries participated.

The baggage handling issue was addressed under the following categories.

- Environment
- Load
- Task
- Human Factors

Environment.

The group considered the most significant environmental risk factor leading to injuries was the design of the narrow-bodied aircraft baggage compartment. During preliminary discussions, it was noted that the design had not altered since the advent of heavy jet transport aircraft. Only the relatively recent, but limited advent of stacking systems (eg ACE and sliding carpet) have attempted to re-engineer this confined workspace.

Other environment factors considered to lead to back injuries were poor baggage cart and baggage transfer system design as well as poor ticket counter design.

The group determined that there were two possible solutions to improve the working environment:

- Development and testing of reliable, mechanical loading systems for narrow-bodied aircraft which significantly reduced or eliminated the manual handling risk,
- development of practical containerisation solutions foe narrow-bodied aircraft.

While the ACE and sliding carpet systems had been reported as reliable, there was little or no research in the past as to their effectiveness from an injury prevention perspective. There is a clear need for more research into the effectiveness of these systems.

Other than some trial developments of containerisation systems for narrow-bodied aircraft in the early 90's in Sweden, there has been very few attempts to provided such systems. It was noted that Airbus Industrie had developed such a system for the A319/A320/A321 but virtual no airlines purchasing these aircraft had purchased the option.

4

Load.

This group felt that the greatest risk factor was the weight and size of luggage. It was noted the NIOSH lifting standard was an unaided maximum lift of 51lb (pound), but the airline standard suggested 70 lb (pound), although most agreed the airline standard was hardly ever enforced and heavier baggage was frequently accepted into the airline systems.
An equally significant issue was considered to be the size of baggage and cargo. Often oversize, large, bulky, awkward items were accepted as general cargo or baggage and these caused significant manual handling risk when loaded into narrow-bodied aircraft.

Consistent airline policy across the industry limiting the weight and size of baggage which will be excepted for uplift needs to be introduced. Manual handling regulations in most western industrial societies already provide such limitations, but the airline industry has generally ignored these regulations.

Task.

The group that reviewed task-related issues, considered there were four high risk baggage handling tasks:

- transfer of baggage from the scales to the delivery belt at ticket counters,
- loading containers and barrows (trolleys) in the baggage sortation room,
- transferring baggage, (containers and trolleys) on the tarmac outside the aircraft and,
- moving and stacking baggage and cargo in the baggage compartments of narrow bodied aircraft.

All solutions for the manual handling task suggested by the group, hinged on automation. Baggage transfer belts at all check-in counters, automatic baggage sorting systems, mechanical lifting aids where manual handling tasks cannot be eliminated, containerisation systems and/or stacking systems (eg. ACE and sliding carpet) for all narrow-bodied aircraft.

Human Factors.

The most significant human-related risk factor was considered to be the age and physical stature of the individuals.

- Due to the confined space of narrow-bodied aircraft baggage compartments, tall people were considered to be at greater risk that shorter persons.
- Age was considered to be a factor because the average age of baggage handlers was thought to be increasing as staff turnover in the modern economic climate has reduced significantly. Where baggage handlers in the past left the area after a few years, it is not uncommon now for most baggage handlers to remain in the role until retirement in their late 50's or even 60's.

Poor employee morale was also considered to be a significant issue when leading to increase in injury reporting. It was thought that during periods of low employee morale, baggage handlers were more inclined to report minor back injuries which would otherwise go unreported. However, this was not necessarily considered to be a negative factor since early intervention to address minor injuries has been shown to be a better rehabilitation strategy.

Another key factor is employee fatigue. Often long shifts are worked and due to recent productivity improvement drives which reduced the numbers in the overall workforce, baggage handlers get no opportunity for rest during the course of the shift, and are required to hurry from one aircraft to another to meet ever increasing schedule demands.

Intervention strategies targeting the individual, with the most likely chance of reducing baggage handler back injuries were supervised general fitness and wellness programs, control of shift duration, manual handling frequencies, and task rotation.

There is a need for further research into the effect of the changing shift patterns, reduced manning levels and increased flight schedules.

4. CONCLUSION

To date, this project has quantified the magnitude of the back injury problem and confimed the need for industry wide action. It refuted the notion that increased training effort would significantly affect the occurrence of baggage handling injuries and highlighted the need for better design solutions to eliminate manual handling risk exposure.

Both the survey of Safety Professionals and the workshop involving Airline Management Personnel, questioned the lack of mechanical assistance devices generally and targeted narrow body aircraft baggage compartments as the highest risk workplace.

In addition to a survey of Baggage Handler opinion still in progress, this project is yet to review the existing in-plane baggage handling systems for Narrow Body Aircraft. Outcomes of both these phases will be presented in a subsequent papers.

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APPENDIX NO. 37:

THE CAUSES AND PREVENTION OF BAGGAGE HANDLER BACK INJURIES: A SUMMARY OF THE LITERATURE

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THE CAUSES AND PREVENTION OF BAGGAGE HANDLER BACK INJURIES:

A Summary of the Literature

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ABSTRACT

Injuries that result from manual handling are the most common suffered by people at work and back injuries are the biggest proportion of manual handling related injuries. Airline baggage handlers, by nature of their work, are exposed to significant manual handling and back injury risk. This paper summarises the literature on the causes and prevention of back injuries to airline baggage handlers. Among the solutions identified were the need for redesign of some aircraft baggage compartments and some ground handling equipment, provision of mechanical assistance devices, both within the aircraft and in baggage sorting rooms at airports, and better maintenance of equipment. The need for improved manual handling training and physical fitness training for baggage handlers were also identified by some authors.

INTRODUCTION

Of all types of injuries that occur in the workplace, injuries related to manual handling are consistently reported to be the most common. The United States Bureau of Labour Relations Statistics reported that 62% of all workplace illness cases in the United States in 1995 were the result of repetitive manual handling trauma (NIOSH 1997). In Western Australia, in the period July 1994 to June 1995, 30% of all lost time injuries, the largest single category, were manual handling injuries which cost $US 1.4 million per day (MHC 1998). Bernard B (Ed) (1997) reported that 60% of lost time injuries due to manual handling in the United States in 1994, were back injuries which, according to *NIOSH (1994[1])*, cost over $US 20 Billion and accounted for 20% of all injuries and illnesses in USA workplaces that year. Back injuries were reported as the most serious injury type suffered by the claimants in 25% of workers compensation claims lodged in Victoria, Australia in the period 1992 to 1994 (*Health and Safety Organisation (1995). Also,* back injuries were reported to be 30% of all New South Wales workplace injuries in the period 1993 to 1995 (W*orkcover New South Wales (1996)*.

The problem of back injury occurrence in airline baggage handlers[50] has been known for many years. A National Safety Council of America, International Air Transport Executive (ARTEX) study of baggage handler injuries in 10 airlines in 1977, found that 340 baggage handler back injuries occurred in that one year of the study *ARTEX (1980)*. *Dell (1997)* found that baggage handler back injuries cost an average of US$21 million per annum across 16 companies over the three-year period of the study (1992 to 1994). *Dell (1997)* also found that 8.5% of baggage handlers suffered back injuries each year with an average annual Lost Time[51] Back Injury Frequency Rate (LTFR) over the period of 41.5 (per million hours worked). More recently, *Gaber (1998)* reported that over

800 people were absent from work each day from Frankfurt Airport due to work related injury and illness. The absences cost US$500 per person per day and two thirds of those injuries were back injures predominantly in the baggage handler workforce.

This paper explores the literature regarding the baggage handler back injury issue. The common findings of authors and their recommendations for injury prevention are summarised. The paper is one in a series by the writer looking into various aspects of the baggage handler injury problem.

METHODOLOGY

Literature searches were conducted using several commercial databases, namely Dialogue, Dialindex, OSH-ROM, CC-Info and ACEL OHS File. Also, OHS journals such as Safety Science, Applied Ergonomics and CCH Journal of Occupational Health and Safety, Australia and New Zealand were searched, as were industry journals such as Boeing Airliner, Flight Safety Foundation Airport Operations Journal and Jane's Airports Review. In addition, conference proceedings from the International Air Transport Executive of the National Safety Council of America, Flight Safety Foundation, Australasian Aviation Ground Safety Council and the International Air Transport Association were investigated.

FINDINGS

Worldwide the airline industry relies heavily on manual handling methods for transferring baggage and cargo. From the time a passenger surrenders their baggage to the airline agent at check-in, until it is stacked into the baggage compartment of the aircraft, it is handled manually up to 5 times in the case of narrow body aircraft and at least twice for wide body aircraft[52] (see Figure 1). Unloading baggage from an aircraft is essentially the reverse of loading, so that from check-in to the time a bag is returned to the passenger on completion of a flight, each bag is handled up to ten different occasions.

Narrow Body Aircraft	Wide Body Aircraft
Transferring bags:	Transferring bags:
✈ From check-in scales to baggage belt	✈ From check-in scales to baggage belt
✈ From belt to baggage trailer	✈ From belt and stacking in container
✈ From trailer into aircraft	
✈ From aircraft doorway into compartment	
✈ Stacking baggage inside the compartment	

Figure 1

Manual Handling Tasks Associated with Passenger Baggage

There is little doubt that these repeated manual handling tasks expose baggage handlers to significant injury risk. In fact, several authors, *ARTEX (1981), Jorgensen K. et al (1987), Hogwood (1996), Berubé (1996), Dell (1997) & Dell (1998)* agreed that poor ergonomic design of narrow body aircraft cargo compartments placed serious limitations on baggage handler working postures and significantly increased the risk of injury (see Figure 2). The baggage compartment of narrow body aircraft is nothing more than a hollow space left for baggage handlers to stack baggage and cargo. Manual handling with restricted working posture is usually the only option available to baggage handlers for the loading and unloading of such aircraft.

Figure 2

Working Inside Narrow Body Aircraft Baggage Compartments

In fact, the poor design of narrow body baggage compartments was also condemned by the baggage handlers themselves. In *Dell (1998)*, a clear majority (87%) of the baggage handlers surveyed felt that stacking baggage inside narrow body aircraft was most likely to cause back injuries.

As a result, there appears to be mounting pressure on airlines and aircraft manufacturers to address the poor ergonomic design of narrow body aircraft baggage compartments. However, fully effective solutions to this problem may not be easy to achieve. Historically the aircraft and equipment manufacturers have only reacted to market demand. As *Briggs (1997)* suggested "*there will have to be airline industry consensus before the aircraft manufacturers will carry out design changes to their aircraft"* and industry consensus may be very difficult to achieve.

Like all business interventions, the business case for any proposed OHS solution needs to demonstrate that the costs of purchase, installation and ongoing operation of the proposed intervention compares more than favourably against the projected ongoing cost of injuries (O*xenburgh (1991)*).

The financial viability of commercial transport aircraft rests with their ability to uplift payload and operate over long distances, the longer the better. Accordingly, manufacturers strive to improve their aircraft designs to increase payload/ range capability and this is usually achieved by maximising the benefits of available technology and minimising the weight of the aircraft structure itself leaving the greatest possible margins for payload and range, thereby maximising economic capability of the design. Certainly the existing narrow body aircraft baggage compartment designs, the empty spaces, admirably meet these aircraft performance criteria. Since the existing narrow body baggage compartment structure weighs very little, it has very little negative impact on payload or range capability.

Accordingly, industry agreement on any proposed solution to the manual handling problem in the aircraft baggage compartment, may only be achieved provided these aircraft performance precepts are not significantly or unduly degraded. Clearly, to gain universal acceptance by the industry, any engineering solution will have to take these performance issues into account and not add significant structural weight to the aircraft. Otherwise, the cost impacts to the ongoing aircraft operation may outweigh the ongoing costs of the injuries presently being experienced by the airlines.

Aircraft performance engineers jealously guard the aircraft design against unnecessary or non-productive weight. In the past, prior to the advent of efficient turbine engines and lightweight synthetic fibre materials, payload margins and economics were usually very tight. Also, at the time, labour costs were much lower, as would have been the cost of injuries, so manually loading baggage into the aircraft was a logical and cost effective process. So it's not surprising that aircraft baggage compartments were little more than empty spaces and manual handling the preferred method for loading.

However, the available payload and range of modern transport aircraft, due largely to the advent of much higher power engines and new synthetic materials stronger and significantly lighter than the metals utilised in the older generation aircraft, is significantly improved. These aircraft performance advances have allowed many other improvements in design, especially in the area of passenger service, comfort and entertainment. However, the design engineers still jealously guard aircraft design against unnecessary weight, and for most of the existing narrow body aircraft, even those benefiting from the latest engine and materials technology, baggage compartment and baggage system design is little different to aircraft designed 70 years ago.

In light of this design inertia, its not surprising that a significant number (44%) of the baggage handlers in the *Dell (1988)* study were so convinced that the aircraft design was sacrosanct, that they felt there was no likelihood of any aircraft engineering redesign solutions being achieved at all.

However, there is some hope for a solution, albeit perhaps a part or interim solution, to the baggage compartment design problems of narrow body aircraft. Some airlines have retrofitted semi-automated systems in baggage compartments of narrow body aircraft. These systems provide a moveable wall which can be positioned near the cargo compartment door and eliminate the need for baggage to be shifted manually down the length of the cargo compartment. Figure 3 depicts the Scandinavian Belly Loading Company "*Sliding Carpet*" system. The American *ACE* (see Figure 4) system is another example.

Figure 3

Scandinavian Belly Loading Company Sliding Carpet Loading System

Although not yet in wide spread use, systems such as *Sliding Carpet* have been installed by some airlines and information available to date is encouraging. *Johansen (1995)* reported a 25% reduction in baggage handler sick leave rates, 50% reduction in the occurrence of damage to baggage and the lining of the baggage compartments and a 3% reduction in the number of baggage handlers required in the operation. *Johansen (1995)* also claimed a $US 2 million saving over the first 3 years of operation of 17 B737 aircraft with the system installed. If these results are what can be expected, the slow rate of adoption of these systems by the industry may change.

However, these systems still require the baggage handler to stack the baggage in the baggage compartment and expose those using the system to some manual handling injury risk. Except for *Johansen (1995)*, no literature was found which assessed the residual injury risk to baggage handlers using these systems[53].

If effective engineering controls cannot be found or introduced, what other solutions are available?

There has also been considerable consensus amongst previous authors (*ARTEX (1981), Dell (1994), Berubé (1996), Dell (1997) & Dell (1988)* that the weight of passenger baggage is a major injury causation risk.

However, very few airlines have successfully addressed this issue. Restricting passenger baggage weight is perceived as commercially unpalatable and airlines that do take such action may be placed at a commercial disadvantage to those that allow passengers to lodge baggage of any weight and size for carriage on the aircraft *(Dell 1997)*.

The ACE Narrow Body Stacking System

Figure 4

Accordingly, if weight reduction is to work as an industry self-regulation strategy, there is a need for industry-wide agreement on what baggage weight limits will be introduced and how it will be managed. Some airlines have introduced such limits with mixed success (reported in *Dell (1994)*), however, the number of airlines worldwide not enforcing any baggage weight limits, far exceeds the number that do attempt to limit the weight of individual items of passenger baggage.

Recently, the International Air Transport Association (IATA), the representative body of airlines world-wide, agreed to introduce a recommendation in the IATA *Airport Handling Manual* that airlines should limit passenger baggage weight because of the injury risk to baggage handlers (***Briggs (1999)***). However, when published by IATA in the 2000 edition of the Airport Handling Manual, compliance by airlines with the IATA recommendation will not mandatory. Accordingly, the commercially unpalatable baggage weight limit is likely to remain little more than a token gesture, unless economic pressure or regulatory intervention occurs.

Economic pressure is unlikely to be forthcoming in the short term. As reported in *Dell (1997*), many airlines do not have adequate financial tracking systems to properly identify the costs associated with manual handling injuries to baggage handlers. In many cases, such injuries are centrally administered and funded, data capture concerning injury causation is poor and little or no true risk analysis is carried out using the compensation information collected within the airlines.

Manual handling intervention is universally high on regulators intervention agendas across most industries and

OHS regulatory bodies worldwide have not enforced their manual handling legislation in the airline baggage handling area. In the past, there is little doubt they lacked the necessary information about the problem, or were unsure if a viable solution existed. However, the evidence is mounting that, while there is no panacea, there are part solutions available to some of the baggage handling risks, and these are not being adopted across the industry.

In contrast, Denmark recently introduced significant restrictions on the amount of baggage or cargo a single baggage handler could lift in a 24 hour period. The Danish Work Environment Service issued a directive to airlines (*DWES (1999)*) operating at Copenhagen Airport limiting each baggage handler working within aircraft baggage compartments to lifting 1500 kg per day and 3000 kg per day for baggage handlers working on the ramp and in baggage rooms.

THESE LIMITATIONS WERE SPECIFIED AS INTERIM MEASURES AND THE DWES FURTHER DIRECTED COMPANIES AFTER SEPTEMBER 1, 2002 THAT *"THE WORK OF LOADING AND UNLOADING AIRCRAFT MUST BE PLANNED AND ORGANISED IN ALL RESPECTS IN SUCH A WAY THAT IT CAN BE PERFORMED IN A MANNER THAT IS FULLY SOUND FROM A SAFETY AND HEALTH STANDPOINT".*

Clearly, real engineering solutions to the manual handling exposures of baggage handlers will be required to satisfy this requirement. While 3 years may be insufficient for the new baggage handling systems to be designed, tested and implemented, there is no doubt that the clock has commenced ticking down on the demise of the current baggage system designs which rely heavily on manual handling, especially if other regulators follow the Danish lead.

Of course, not only will these requirements impact on aircraft baggage compartment design. As the *Dell (1997)* and *Dell (1998)* studies confirmed, there is a need to redesign the baggage handling and sorting systems to reduce injury risk. *Briggs (1997)* predicted that there has to be the will within the industry or pressure from the regulators for such changes to take place.

The pressure it seems is now beginning to be applied and past application of only rudimentary ergonomic principles, such as integration of average height and reach distances to account for the needs of the system users will no longer be considered satisfactory.

Figure 5

The AirGro *"ErGoBag"* Mechanical Assistance Device

As a minimum, mechanical assistance devices, such as ErGobag (see Figure 5), which are now commercially available and could be retrofitted at many existing airports, will need to be installed to meet the needs of all baggage handlers.

Existing equipment will also need to be redesigned to permit mechanical lifting aids to be utilised. For example, existing aircraft baggage container designs may need to be modified so that devices like ErGobag can be used. Container tops may have to be open, or at least have lids which can be opened, so that roof mounted systems such as ErGobag can be utilised. Alternatively, new mechanical assistance devices may need to be designed which can access existing containers through the side openings and negate the need for baggage handlers to reach into containers while lifting baggage and cargo (see Figure 6)

Figure 6

Manually Loading Wide Body Containers

There needs to be a holistic view taken of the manual handling problems in passenger baggage and cargo transfer. It is a fact that airport baggage sortation system and ground equipment design is linked and also dependent on aircraft systems design. Clearly, the aircraft manufacturers are the key to providing long-term design solutions. Appropriate changes in aircraft baggage systems design to address the manual handling issues are needed as a catalyst for wide spread change.

Meantime, while the engineering solutions to the problems presented by existing aircraft and airport designs are devised and implemented, the industry must act in the short term to improve other aspects of the overall manual handling injury prevention system.

As the *Dell (1997)* & *Dell (1998)* studies both confirmed, there is a need to provide better manual handling training for baggage handlers. In many airlines manual handling training is almost non existent. Also, there is a need to improve maintenance and serviceability of existing baggage system equipment, both within the aircraft and at airports. Ergonomic risk to baggage handlers can increase exponentially when mechanical systems malfunction and baggage handlers are tasked with moving loaded containers and pallets which were never designed to be moved manually (see Figure 7)

Airlines must place the same emphasis on the maintenance of baggage systems, as is the norm for other safety related aircraft systems.

Figure 7

Pushing Loaded Pallets and Containers inside Aircraft

The literature remains divided on the issue of back support belts as injury prevention aids. There seems to be as many papers supporting their use as there are recommending their non-use. Despite many authors recommending caution (see for example *Perkins and Bloswick (1995)*, *NIOSH (1994*[2]*) and NIOSH (1997)*, reports of successful implementation programs continue to occur. For example, *Gaber (1998)* reported that Frankfurt Airport have recently recommended use of back belts by airport staff following a study of 200 subjects that showed a 4% reduction in back injuries amongst subjects who used back belts as part of an integrated physical back care training program. While at first glance not sounding like a worthwhile exercise, a 4% improvement results in significant saving in injury costs, given the epidemic proportions of the problem, and while the time for adequate engineering controls to be developed ticks on, a 4% improvement appears better no improvement at all.

There is no doubt the baggage handler back injury problem is begging for a short, as well as long term solution.

CONCLUSIONS

There was consensus amongst authors that the narrow body aircraft baggage compartment was the baggage handler workplace most likely to cause back injuries. Restricted postures required to be adopted by baggage handlers in these baggage compartments exacerbate the manual handling problems associated with loading and unloading passenger baggage.

Aircraft manufacturers need to review aircraft baggage compartment design criteria to take manual handling injury risk into consideration. It is no longer acceptable to just provide a cavity within the aircraft where baggage is expected to be stacked by personnel.

In-plane retrofit systems, such as *Sliding Carpet* and *ACE*, which existing evidence suggests reduce exposure to manual handling injury, should be seriously considered by all airlines that operate narrow body aircraft. Those airlines that already have installed these systems should share their experience with others, in the interests of injury prevention.

There needs to be a quantum improvement in airport building and baggage systems design in the area of ergonomics. Past reliance on designing for the dimensions of the average baggage handler must come to an end. Unless the manual handling tasks are entirely eliminated, future systems must be designed to maximise the ergonomic advantage for all system users, not just those baggage handlers with average dimensions.

Mechanical lifting aids, such as *ErGoBag*, should be considered by all airport owners and operators. There are many places in existing airport baggage sorting rooms where these aides could be retrofitted and significantly reduce the manual handling injury risk.

All airlines need to review their equipment maintenance programs. The serviceability of ground equipment and aircraft loading systems must be maintained to a high standard. The risk of injury to baggage handlers increases significantly when personnel are required to manually handle the heavier loads that were intended to be moved by the failed equipment.

While long term solutions to the manual handling injury problem are being developed, there is an urgent need for the industry to place a limit on the weight of baggage to be accepted by the airlines. To be effective, the weight limit must be applied across the industry so that the injury risk from baggage handling is not exacerbated by over weight and heavy bags. Furthermore, systems should be developed by all airlines to tag baggage and label cargo with accurate weights. This will permit baggage handlers to properly prepare for each lift and assess the injury risks of handling items of baggage and cargo.

Some authors clearly expressed a desire for improvements in the manual handling training provided to baggage handlers. Baggage handlers cannot be expected to perform their duties at optimum level, unless they have acquired the appropriate skills and techniques available. Comprehensive back care and lifting technique training should be provided by airlines as a minimum.

The aviation industry associations have a clear role to play. There is a need to set realistic standards across the industry, which address the baggage handlers' injury risks. Their secondary role is to provide a focal point for bringing all the stakeholders together. The long-term solution relies on the co-operation of all parties; the airlines, airport operators, equipment and aircraft manufacturers, and the baggage handlers.

Without industry co-operation, long-term solutions are unlikely to be forthcoming, unless the OHS regulators around the globe overcome their current inertia.

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